DOE/CH/10432--1

DE91 009140

ENVIRONMENTAL CONSEQUENCES OF ENERGY PRODUCTION

Proceedings of the Seventeenth Annual Illinois Energy Conference

CHICAGO, ILLINOIS
October 19-20, 1989

Sponsored by

Energy Resources Center
The University of Illinois at Chicago

in cooperation with

U.S. Department of Energy

U.S. Environmental Protection Agency

Illinois Department of
Energy and Natural Resources

Illinois Environmental Protection Agency

Illinois Commerce Commission

Citizens Council on Energy Resources

and

Chicago Association of Commerce
and Industry

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

Library of Congress Catalog Card Number 90-080328

Published in the United States of America
Energy Resources Center MC/156
The University of Illinois at Chicago
P.O. Box 4348
Chicago, IL 60680

recycled paper

PLANNING COMMITTEE

Chairman:

James P. Hartnett, *Energy Resources Center,*
University of Illinois at Chicago

Conference Coordinator:

James J. Wiet, *Energy Resources Center,*
University of Illinois at Chicago

Eugene Abraham, *Sargent & Lundy Engineers*
Eckhard Blaumueller, *Peoples Gas Light and Coke Company*
Ralph Dunn, *Illinois State Senate*
William J. Geekie, *William J. Geekie & Associates*
Patrick Giordano, *Attorneys Foley & Lardner*
Del Haschemeyer, *Illinois Environmental Protection Agency*
N. Richard King, *Illinois Commerce Commission*
Howard Learner, *Business and Professional People in the Public Interest*
Kurt D. Lindahl, *Natural Gas Pipeline Company*
John C. Marlin, *Illinois Pollution Control Board*
Keith W. McHenry, *Amoco Oil Company*
John S. Mead, *SIU Coal Research Center*
Samuel R. Mitchell, *Chicago Association of Commerce and Industry*
James "Pate" Philip, *Illinois State Senate*
Hilary J. Rauch, *U.S. Department of Energy*
James F. Rea, *Illinois House of Representatives*
Thornton Ridinger, *Illinois Department of Commerce and Community Affairs*
Robert B. Rosenberg, *Gas Research Institute*
Marilyn Rosenzweig, *League of Women Voters of Illinois*
William Ryan, *Commonwealth Edison Company*
Alan Schriesheim, *Argonne National Laboratory*
Steve Stalcup, *Citizens Assembly*
Edwin Werneke, *Northern Illinois Gas Company*
Kenneth Westlake, *U.S. Environmental Protection Agency*
Charles H. Williams, *City of Chicago*
Karen Witter, *Illinois Department of Energy and Natural Resources*
Porter J. Womeldorff, *Illinois Power Company*

CONTENTS

Foreword, *James P. Hartnett* 1

Introduction, *Hilary Rauch* 3

I. Keynote Presentations

1. A Clean Environment and a Prosperous Economy: Can We Have Both? *Gaylord Nelson* 9
2. A Strategy for a National Energy Policy, *Vito A. Stagliano* 19
3. International Dimensions of the Environmental Problem, *Zdzislaw Kaczmarek* 23

II. Urban Pollution

4. Baseline Air Quality for Northeastern Illinois, *Michael J. Hayes* 35
5. An Update on the Chicago Federal Implementation Plan, *David Kee* 43
6. The Los Angeles Air Management Plan, *Carolyn Green* 55

III. The Acid Rain Problem: Implications for the Midwest

7. Past, Present and Future of Acid Rain Legislation, *Shelly Fidler* 65
8. Economic Impacts of Acid Rain Legislation on Illinois and the Midwest, *David Baker* 69
9. The Canadian Response to the Acid Rain Problem, *Sherri Watson* 89

IV. Global Warming

10. Global Warming: An Overview, *Kenneth E. Kunkel* 97
11. The Science and Politics of the Greenhouse Effect: Collision Course? *Patrick J. Michaels* 115
12. Greenhouse Warming: Science vs. Consensus, *Richard S. Lindzen* 139
13. Improved Monitoring for Detecting Global Climate Change, *Henry F. Diaz* 161

V. Strategies to Minimize Environmental Damage

14. Roles of Energy Efficiency in Reducing Environmental Impact, *William W. Schertz* 173
15. Strategies for Combating Urban Pollution, *Jerrold L. Levine* 181
16. Environmental Alternatives for Transportation, *Timothy L. Sprik* 191
17. Disasters Generate Policy Crisis Management, *David J. Zwiesler* 203
18. Energy and Environment: Policy Options and Opportunities, *Robert Miller* 209

FOREWORD

The Seventeenth Annual Illinois Energy Conference entitled "Environmental Consequences of Energy Production" was held in Chicago, Illinois on October 19-20, 1989. It was organized by the Energy Resources Center, University of Illinois at Chicago with major support provided by the U.S. Environmental Protection Agency, the U.S. Department of Energy, the Illinois Commerce Commission, the Illinois Department of Energy and Natural Resources, the Illinois Environmental Protection Agency, the Citizens Council on Energy Resources and the Chicago Association of Commerce and Industry.

The conference program was developed by a planning committee that drew upon Illinois energy and environmental specialists from the major sectors including energy industries, environmental organizations, research universities, utility companies, federal, state and local government agencies, and public interest groups. The planning committee was brought together for a full-day session where they were asked to assess the technical, economic and institutional issues surrounding energy production and the related environmental problems. At the conclusion, four major topic areas were identified upon which the conference sessions were developed. The issue areas were:

1. Urban Pollution: Where Are We Now and What Needs to Be Done in the Future.
2. The Acid Rain Problem: Implications of Proposed Federal Legislation on the Midwest
3. Global Warming: An Update on the Scientific Debate
4. Strategies to Minimize Environmental Damage

Subcommittees were then formed with the task of designing the four plenary sessions, keeping a focus on the state/regional impacts of each particular topic. The subcommittees also recommended several keynote speakers who would place the critical environmental issues into the national/international context. For these exceptional efforts, we express our thanks to the planning committee and subcommittee members who worked hard to suggest pertinent issue areas and speakers.

Appreciation also is extended to the outstanding speakers whose papers appear in this publication. The excellent quality of the program reflects considerable time and effort on the part of the speakers in the preparation of the presentations. In particular, we extend a special note of appreciation to the keynote speakers Senator Gaylord Nelson, Vito Stagliano, and Zdzislaw Kaczmarek who set the high standards of the conference. A word of thanks also is extended to the session co-chairpersons and the panel moderators who kept the discussions lively and in focus. In addition, a word of appreciation is given to the conference sponsors and the University of Illinois staff, Marion B. Deloney, Yvonne V. Harris and David Balderas, who handled the detail work of the conference. Finally, I thank James Wiet, who managed the conference activities from beginning to end.

I hope you find these conference proceedings useful in providing current policy information on energy and environmental problems facing the Midwest and the Nation.

James P. Hartnett
Planning Committee Chairman

INTRODUCTORY REMARKS

Hilary J. Rauch, Manager
Chicago Operations Office
U.S. Department of Energy

The Illinois Energy Conference has for years been an intellectual crossroads for those involved in energy policy issues in the Midwest. With remarkable accuracy, James Hartnett, his staff, and those of you who have helped plan this meeting have focused on the right issues at the right time. That is true again this year.

For years, this conference has been a great joust. Regulators have squared off with free-marketeers. Spirited battles have been joined between common carriers and energy users. And we have all seen the sparks fly when environmentalists have thrown down the gauntlet in front of energy producers, and sometimes, vice versa!

Since last year's conference, there have been several changes on the national energy scene, not the least of which was a change in our national leadership. Secretary of Energy James D. Watkins has made the development of a viable National Energy Strategy a major Administration objective. Vito Stagliano, Deputy Director of DOE's Office of Policy, Planning and Analysis addresses this effort.

Let me emphasize a couple of significant differences between this new Administration and those that preceded it. Admiral Watkins has committed to developing a National Energy Strategy that contains specific recommendations for action in the near, mid and long term. These will be actions, not descriptions of general policy, which dominated earlier efforts. Secondly, it is the Admiral's intent that these recommendations be linked directly to the federal energy research and development budget, and to its formulation, so that strategy and action can be closely tied. These are ambitious goals that have never before been successfully incorporated into national energy policy planning.

Public hearings are taking place across the nation to provide broad public and special interest input into this process. The Admiral has resisted the urging of some in Congress and industry to move ahead in the interest of supposed efficiency and speed without that external input.

As a manager working directly for Admiral Watkins, I can attest that his public statements about the importance of public participation in the development of a national energy strategy are heartfelt.

For those of you who are skeptical of the value of public participation in such processes, I urge you to review the lists of prestigious and expert testifiers who have taken the time to give the Department the value of their opinions. These are leaders in science, industry and academe, as well as interested citizens with something to say about their stake in the nation's energy future.

Concern about environmental issues has been a major theme emerging from those hearings, and it has been echoed in Congressional proceedings, news media reports, and countless other public arenas. Based on such diverse indicators as the cover of *Time* and the maiden voyage of the new Greenpeace vessel "Rainbow Warrior," 1989 has been the year of the Environment: the greenhouse effect, deforestation, global warming, depletion of the ozone layer, the Exxon Valdez, the $100 billion price tag for cleaning up the Great Lakes, the Clean Air Act amendments, acid rain, nuclear waste disposal. The list goes on and on.

These issues have risen to such prominence that they have displaced many others on the national agenda, at least in terms of the public's attention. And perhaps this is overdue.

Maybe we have waited too long for this joust. I am sure that some will argue that we have already waited too long to take decisive action on critical environmental and energy issues.

In the next two days, you will hear from some speakers that the signs of impending grave damage to the environment from energy production have been there to read for a number of years -- and we were just not ready to act.

Others will contend that the message has not been received for good reasons – that our data are still inadequate for the task, and the message is too unclear to justify draconian measures and precipitous action – that we risk doing more harm than good.

Where is the balance? The wise middle ground? The truth of these divergent views?

This 17th Annual Illinois Energy conference represents one important attempt to bring balance and perspective into this debate over energy and environmental issues as they impact Illinois and the Midwest region.

From this perspective, the conference program retains its track record for farsightedness. We will attempt to determine what we really know about many of these difficult, interrelated problems. And more importantly, we will try to determine what action can be taken, and perhaps must be taken, in the near term.

Thank you all for joining us.

I. KEYNOTE PRESENTATIONS

A CLEAN ENVIRONMENT AND A PROSPEROUS ECONOMY: CAN WE HAVE BOTH?

Gaylord Nelson
Counselor
The Wilderness Society

Once when Prime Minister Disraeli was asked by an intellectually undistinguished member of Parliament whether Disraeli thought it advisable for him to participate in the upcoming debate, Disraeli replied, "I don't think you should enter this debate. It would be better if the House of Commons was to wonder why you did not speak than why you did." With no Disraeli around to save me, I am now about to expose my limitations and speak on environment, resource and conservation issues to an audience that includes professors and others with considerable expertise in ecology, life systems, resource and environmental issues. Nonetheless, I am willing to venture a viewpoint on some of these complicated matters knowing, as you do, that the total of our knowledge of the world ecosystem is minuscule compared to what we do not know. So, we are all in a situation of what might be described as shared ignorance. Happily, I will share some of mine with you.

For some four decades, I have concerned myself with environmental and resource issues, though quickly I realized the more I learned, the less I knew. This is so because the subject matter is all-encompassing. It is the air, the water, the soil, the forests, the oceans, the rivers, all living things in the seas, on the land, the relationship and influence of each on the others, plus economics, politics, philosophy and more. So, obviously, we will never know or understand more than a small bit about the endless intricacies of nature's works and how the world habitat is effected by it all. Nevertheless, we can learn and understand the general principles that should guide our conduct as a society if we are to preserve a livable habitat. The general principle can be stated in many ways. The proposition is, quite simply, that we must strive to conduct our activities in such ways as to protect the integrity of the ecosystem and its resources that sustain life and determine its physical quality. Minimum achievable interference with natural systems must be our guideline.

If you were all asked the question, "What, in the long run, is the most important issue facing humankind on the planet?", how would you answer?

IS IT

The economy? Jobs? Free speech?
Freedom of religion? Freedom in general?

IS IT

World peace? World hunger?
Discrimination? Civil rights?

IS IT

The threat of nuclear war?
The viability of democratic institutions?

Just what is the most important issue of all?

Well, we probably could argue all day and all night without even agreeing on a list of the ten most important issues, let alone agreeing on the single most important issue.

BUT

...if you think carefully about it, there is one issue that stands alone, above all others. Right now, and in the long haul into the next century and the centuries after that, no other issue is more relevant to the quality of life for the human species than the status of our resources – air – water – soil – minerals – scenic beauty – wildlife habitat – forests – rivers – lakes – oceans. It is this resource base that defines the habitat and the limitations for survival of all species, plant and animal, including humankind.

Indeed, these resources determine precisely the physical condition of our lives on the planet and influence dramatically the human condition, spiritually, intellectually, and philosophically. There is simply no other issue with a more compelling entitlement to our attention and our time. And yet, strangely, this issue that is of primary consequence for this and all future generations play a secondary role to a multitude of other less important issues.

As rational individuals, we certainly must understand, as I think we do: That the viability of our economic system depends upon our resource base; that issues of war, peace, hunger and revolution are mightily influenced by the availability of resources; that nuclear war is not inevitable but environmental disaster is inevitable unless we act in a timely fashion; that in many corners of the earth population numbers already far exceed the supply of resources necessary to sustain even a minimum, acceptable quality of life; that, indeed, our physical well-being, our standard of living, the quality of our lives is directly, specifically and tightly tied to our resources.

If all of this is so, and clearly it is, then why do we not have the foresight and the will to act collectively to meet the challenge before the damage is beyond repair?

The central core of the problem is, I think, that the various political, religious, economic and social power structures which set our goals and guide our direction have their own institutional agendas which take priority over everything else: The next election is the first order of business, not the next generation or the next.

Business and industry are primarily concerned about profits this year and next year.

Labor unions worry about jobs today and tomorrow.

Farmers and their organizations worry about the current price of corn, soy beans, wheat, milk and the mortgage payment.

Religious institutions worry about today and the hereafter.

Educational institutions are heavily pre-occupied with training their students for jobs in today's marketplace albeit they do have a broader intellectual mission that affords some hope that they will give us a new generation with a better grasp of the environmental issue and a stronger commitment than past generations.

While the mission of these institutions as I have just described them may be somewhat simplified, the important truth is that long-range resource issues are not a significant institutional priority for any of them.

And, unfortunately, individuals, the public, so to speak, tend to conduct themselves much like institutions in the sense that they are pre-occupied with minding the store, responding to the pressures of daily events and postponing hard decisions on pervasive long-term problems under the illusion that delay won't cost very much, that we can address the problem at another time. So it goes from one generation to the next.

Until we understand that the problem is urgent, right today as it was yesterday and the day before; that every delay exacts a price, levies a hidden tax, imposes a cost that ultimately will impoverish us; until we understand, and believe, and are willing to act on the proposition that the highest and first priority of our society must be to preserve the integrity and viability of those ecosystems that sustain us and all other creatures; until then we will continue to delude ourselves with the seductive notion that we are addressing the heart of the matter, when, in fact, we are merely tinkering at the periphery of the problem.

Just a little more control of air and water pollution; just a little more protection of ocean estuaries and salt marshes; saving a few hundred thousand acres of wetlands from endless destruction; preserving a few million acres of wilderness and wildlife habitat; modest reductions in the use of herbicides and pesticides; reducing the pace of soil erosion; deploring the depletion of aquifers; cleaning up a few hazardous waste dumps while proliferating the production of new toxins; lamenting the siltation of spawning grounds while cutting the forests that protect them; and then, topping it all off by celebrating Arbor Day, is not a prescription for meeting the challenge we face. It may make us feel good, but the effort is inadequate and doomed to failure.

I don't mean to suggest that we haven't made some significant progress here and there in the last decade and a half or so. Indeed the most important advance since Earth Day has been the revolutionary change in the public's understanding of environmental issues. That is vital because public understanding and support is necessary if significant progress is to be achieved.

One more revolution is needed. That will come when the President, the Congress and the public put this issue on the agenda of top national priorities along with the economy and war and peace.

That is bound to happen sometime. The only question is . . . when? And, will it be soon enough?

Of course, we still have to deal with those powerful forces in the country who do not believe the problem is serious, and therefore, the environmental laws and standards are unnecessary and should not be enforced. There are others who think we cannot afford a clean environment, and there are those who oppose any governmental interference in the marketplace at any time, under any circumstances. They believe the free marketplace, good intentions and competition will somehow resolve this problem along with all others in due time. This is the Environmental Supply Side School.

They proclaim, for instance, that their supply-side, self-help, free market, do-it-yourself environmentalism will work if we will all just calm down and give it a chance for a decade or two. If, for example, you go into the free marketplace to buy some fresh air and none is available, just hold your breath, and as the demand increases, the price will rise and the classic forces of supply and demand will take over; then there will be an abundant supply, the price will fall and even the poor people will be able to buy some. It all sounds pretty good if you don't think about it too hard.

Well, the fact is we are going to have to think about it much harder in the future than we have in the past. As we all know, our resource problems are global as well as national and thus require international cooperation on an unprecedented scale. If we are to live in harmony as passengers on the "spacecraft earth," as Adlai Stevenson once described our planet, then we must understand and cooperate with each other. We have a long way to go. At the Congress of Vienna in 1814-15, when Prince Metternich was informed that the Russian Ambassador had just dropped dead, he paused for a moment or two and then asked: "What could have been his motive?"

We ask the same question today of the Soviets that Metternich did, and they ask the same of us. Someday, and it cannot be too soon, the two superpowers must succeed in de-escalating the arms race and begin cooperation on a global basis with all other countries in the vital enterprise of better husbanding those resources which determine the condition of our survival on the planet.

Over the past four or five years we have, even more frequently, heard the argument that high environmental standards cost too much. They put an excessive and unnecessary burden on business and industry. The costs, they say, exceed the benefits.

Those who want to use the benefit-cost assessment to weaken support for environmental mandates do not include in their assessment all societal costs and benefits, only those that are easily quantifiable in current dollar costs to the polluter and measurable on the consumer price index. In their computations they do not include the societal cost of a polluted river, a lake or forest destroyed by acid rain, an aquifer poisoned by toxic chemicals, a wildlife refuge destroyed by selenium or any one of dozens of other societal costs.

If all costs and benefits are included, the case is clear beyond question that preserving a clean environment is a profitable investment. Many environmental critics disagree or, more likely, haven't given the matter any serious consideration.

A year or two ago, I participated in a conference organized around the theme, "The Economy and the Environment: Need We Choose?"

Those who would dramatically weaken environmental protection claim we must, indeed, make a choice between the two. They assume the two are separable and must be addressed as discrete entities standing alone. They are wrong by every rational standard of measurement. I assume we are using the word "environment" in its broadest context to include all physical resources – air, water, soil, scenic beauty, minerals, and forests. They are all part of the environment and inseparable from it. The appropriate generalization to be made, I think, is that the economy and the environment are inextricably intertwined; a degraded environment and a poor economy travel hand-in-hand. Jeremy Rifkin recently stated the proposition simply and clearly as follows: "The ultimate balancing of budgets is not within society, but between society and nature."

Each incremental degradation of nature's resources – the air, the water, the soil, forests, scenic beauty, habitats – is quite simply a dissipation of capital assets which ultimately will be paid for by a lower standard of living and a lower quality environment.

Can anyone tell us what the monumental economic and recreation loss to the nation will be unless we move now to save our lakes from acid rain?

What is the economic value of the protein sources in the oceans and the water in our rivers? If we continue to destroy the salt water marshes and pollute the estuaries and the shallow waters of the continental shelf which provide the breeding habitat of most marine creatures, we ultimately will destroy the productivity of the oceans. Has that been factored into the economic equation in the debate over clean water standards? The answer is, no, it has not.

It is not cheaper to clean up the Mississippi River and keep it clean than to leave it dirty, so that every city, every municipality and every industry from Minneapolis to the Gulf of Mexico takes out dirty water, launders it and returns it polluted again?

These and one hundred other questions can be asked and every time the answer will be that it is far better for the economy and cheaper to maintain a clean environment than a dirty one.

We are now approaching the 20th anniversary of Earth Day 1970. An estimated 20 million people participated in that dramatic event including some 10,000 schools, 2,000 colleges and almost every community in the United States.

The main purpose I had in mind when I planned Earth Day in 1970 was to organize a massive nationwide grassroots demonstration of public concern for the environment which would get the attention of the politicians and force the environment issue into the mainstream of political dialogue. It was a smashing success. We achieved the objective. The politicians got the message, and they responded with major legislative initiatives at the national, state and local levels.

These initiatives addressed a broad spectrum of important issues involving air pollution, ocean, lake and river pollution, hazardous wastes, pesticides and solid waste disposal, to name a few.

While these initiatives have been useful and indeed have had dramatic impacts here and there, nonetheless a continuance of efforts at current levels will fall far short of what is needed and will not prevent continued steady environmental decline.

The resiliency of the living planet has already been dangerously comprised. It is rapidly losing its capacity to renew itself. The insults to the land, water and air are too many and too massive.

In short, many threads of the net that hold the world ecosystem together are breaking and unravelling. Only a massive, coordinated worldwide effort will save what is left of the natural world and give nature a chance to repair some of the damage we have caused.

If this sounds like alarmist talk, it is, because the situation is nothing short of alarming.

Plans for a worldwide Earth Day in 1990 are well underway. If Earth Day 1970 is any guide of what to expect, and I think it is, this will be the largest grassroots demonstration in history.

The single most important objective of this 20th anniversary celebration is a worldwide public demonstration so overwhelming that it literally shakes the political leadership of the world out of its lethargy and galvanizes it into a monumental cooperative effort to stop the deterioration of the planet and begin the restoration.

It is time our leaders recognize that in the long haul the state of our environment is far more important than the threat of nuclear war, missile gaps, star wars, crime on the streets, the national debt, the foreign trade deficit, communism in Nicaragua, world hunger, the current state or the economy or any number of other issues that occupy the front pages of our daily newspapers.

Every compilation of important environmental problems always includes air pollution, water pollution, global warming, hazardous wastes and a dozen other concerns but, strangely, the two most important environmental problems, clearly ranking at the top of the list, are never mentioned.

Among these two is the truly abysmal dearth of political leadership at the highest levels here and elsewhere around the world. Leadership, not the lack of scientific and technical knowledge, is what hobbles our progress. We have enough information to advance on many more fronts, much more rapidly. However much scientific data we may accumulate, it is quite useless without leadership at the presidential level. The best we have had at that level is a little positive tinkering and pleasant sounding rhetoric now and then, all of it woefully inadequate. The worst is the recent eight years of active negativism.

The other issue, and no doubt the most important, is the absence of a pervasive conservation ethic in our culture. This is a high priority cultural problem which we must strive mightily to cure by education and example in our homes, schools, churches and other institutions. If we are going to infuse our culture with a conservation ethic that will guide our conduct as individuals and as a society, don't look to my generation, look to yours. My generation doesn't have the time to do it and unfortunately, we came to an appreciation of the monumental significance of the issue too late.

Yours must become the conservation generation. You have it in your power to make a difference – a vital difference in the education of our children and the political course of the nation. Seize the opportunity, persist in your efforts, don't let go and you will prevail. A good way to begin is to participate in the 20th anniversary Earth Day activities on your campus next April.

As we look to the decades ahead we must very soon recognize that our present-day focus on the resource issue is far too narrow and superficial. It touches only the visible tip of the iceberg. It is going to be necessary to make many jarring course corrections that will lead us a different direction from which we have gone since the founding of the Republic. For two hundred years, it has been the prevailing philosophy of this society that our resources were boundless, that we could dissipate and exploit them with lavish extravagance without end. We have uncritically assumed that the vast quantities of toxic chemicals, hazardous wastes and all other pollutants that society produces could be safely vented into the air, dumped in the oceans, lakes, marshes, rivers and on the land because nature would somehow contain or neutralize them. This, of course, was not so. Nature's capacity is limited and that capacity has been exceeded in many places and in many ways quite some time ago.

In the short run, some very modest temporary benefit to the economy might result from relaxed environmental standards, but it would be dangerous and enormously expensive. If we do that, it simply means we are borrowing capital from future generations and counting it on the profit side of the ledger.

Quite apart from the ethical questions involved, there is simply no way that a future generation could replace the capital we borrow from them because we cannot restore a polluted ocean or a polluted lake.

The ultimate test of man's conscience is his willingness to sacrifice something today for a future generation whose words of thanks will never be heard.

What is urgently needed right now is strong, vigorous, imaginative and courageous leadership from President Bush and President Gorbachev. They have it in their power to alter dramatically the course of history if they will but grasp the opportunity.

The cause is right. The time is ripe. The world is ready. Mr. Bush and Mr. Gorbachev should begin by formally declaring an end to the cold war and the beginning of a new era.

The Soviet economy is a shambles. It desperately needs relief from the burden of unproductive military expenditures. So does the United States. The national debt overhangs the economy, saps the vitality of our whole economic and social system, weakens our competitiveness and distorts national priorities. Both nations would benefit from a drastic reduction in military expenditures and a reallocation of resources to the environment and other socially productive enterprises.

President Bush would inspire the world and give it the dramatic leadership it yearns for if he would propose that the United States and the Soviet Union mutually reduce military expenditures by 50 percent in the next 10 years and another 50 percent in the following decade with half the annual savings allocated to husbanding the ecosystem of the planet. Under this proposal everyone is a winner – there are no losers.

Of course there will be strong, strident opposition from the hard liners, the cold war warriors in both the United States and the Soviet Union. Nothing frightens them more than the threat of world peace.

This is not unilateral disarmament; it is not idealism run amok; it is, plainly and simply, hard-nosed realism. How much longer are we and the Soviet Union going to expend a total of $600 billion a year on weapon systems that put us both in greater jeopardy while degrading and destroying the very resource base that sustains us?

In an article on nuclear war, two distinguished scientists, Dr. Wiesner and Dr. York, concluded that: "Both sides in the arms race are . . . confronted by the dilemma of steadily increasing military power and steadily decreasing national security. It is our considered professional judgement that this dilemma has no technical solution. If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation."

Once Mr. Bush and Mr. Gorbachev reach an agreement in principle, the iron curtain countries, Western Europe and most other nations could be persuaded to follow because it would also serve their own best interests.

Very few Presidents are afforded the opportunity to achieve greatness. Those who did, achieved it because they successfully met a major threat to the security of the nation: war, social turmoil, economic chaos. These were the challenges faced by Washington, Lincoln and FDR.

Now, for the first time in history, the nation is confronted with a challenge far more serious than any war or economic depression.

Mr. Bush is the first president in contemporary times to define himself as a conservation president. He has a golden opportunity to grasp this issue and lead the world. The United States is the biggest industrial power – and the world's greatest polluter. This nation has an obligation to set an example.

Whatever else President Bush does in his presidency will fade into distant memories, but if he successfully initiates the battle to preserve the integrity of the planet, he will be remembered as long as history is written.

A STRATEGY FOR A NATIONAL ENERGY POLICY

Vito Stagliano
Acting Associate Deputy Under Secretary
Office of Policy, Planning and Analysis
U.S. Department of Energy

I work for a department whose responsibilities include the management of some of this nation's most intractable problems. Energy affects virtually every aspect of our economic and social life, and every American has a stake in energy policy. It is little wonder that for years it has been practically impossible to forge a consensus on how this nations' energy sector is to evolve.

President Bush and Secretary Watkins are determined to craft a blueprint that will allow this nation to assure itself of the energy it requires for its economic well being, while confronting and managing the environmental consequences of energy production and use. I will be quick to add that a blueprint is not a central plan. President Bush and Secretary Watkins are clearly committed to policies that allow markets to play their proven role as efficient allocators of resources. They will add to this allocation process, the allocation of responsibility for environmental quality.

WHERE WE ARE

Before I launch into a discussion of Federal efforts to develop a National Energy Strategy (NES), it might be useful to summarize what our energy condition is. Critics are fond of depicting the United States as a self-indulgent energy wastrel. I do not subscribe to that depiction, and I would like to tell you why.

In the last 15 years, the United States has demonstrated an impressive ability to improve its energy performance in response to changing and unpredictable market conditions. Today we use about 7% more energy than we did in

1973, however we are powering an economy that is nearly 50% larger than it was in 1973. We have added 20 million homes and 50 million vehicles to our stock. We are more efficient in our energy consumption in almost every sector of the economy. Our cars, our homes, our buildings, and our manufacturing processes are all more energy efficient than they were just ten years ago. The cumulative energy savings we have achieved represent a gift to ourselves of over $900 billion since 1973.

These achievements are all the more impressive for the fact that the price of our energy has remained far below the price that consumers pay for energy in all the developed world. And, unlike the rest of the world, it was our deregulated economy that provided the impetus for this performance. If you hear invidious comparisons between U.S. and other nations' energy consumption patterns, you might remind the critics that the differences are not due to American inefficiencies. They are due rather to differences in how economies are structured. Our patterns of energy usage, like those of other nations, are dictated by geography, by social and economic organization, and by the comfort and security we provide for ourselves.

On the environmental side, and with due respect to the very serious problems that confront us in air and water pollution, in toxic waste management, in ecological change, we also can point to exemplary American behavior. We are two generations ahead of Europe and Asia on legislation and implementation of environmental policy and law. Most of the rest of the world burns mostly leaded gasoline and operates vehicles devoid of even elementary pollution control devices. Air quality is better in most American cities than in the urban environments of most industrialized and developing nations because we have invested heavily in controlling emissions from our smokestacks. The quality of our water is also better than can be found in the developed world. So is our water quality. And so, really, is the quality of life that Americans enjoy.

WHERE WE ARE HEADED

We are headed towards improvement and to international leadership in addressing difficult issues by setting public policy standards that other nations are likely to follow. We are bringing into our investment calculations the environmental costs that economists in the past defined as an externality. The President's Clean Air proposal sets the tone for how far we are willing to go in order to further reduce the harmful emissions that are the consequences of the energy consumption structure we have collectively built.

The President's National Energy Strategy (NES) will be consistent with this nation's clear desire to enhance economic efficiency, foster growth, and improve environmental quality. Energy and the environment should not, cannot, be mutually exclusive policy options.

NES PROCESS

In marked contrast to the approaches of his predecessors, Secretary Watkins has undertaken the development of the NES without preconception. The contents of the NES will not be determined by doctrine or ideology. The NES will be constructed by common sense, setting aside policies that are extreme at either end of the political spectrum. The builders of the NES know that markets do not work perfectly. They also know that the historical evidence suggests caution of proposals that substitute public for private decisions.

Secretary Watkins – who is very experienced in the ways of bureaucracies – wants to hear about energy policy first from those who actually have to live with it. And those who have to live with it do not reside in the Department of Energy. To that end, he conducted an initial series of fact-finding public hearings during the summer. He will conduct a second, longer, series starting in November, and he will invite most of the Cabinet to join him in appreciation of how vast and complex the energy economy really is. He wants to pay attention to local and state issues, constraints, and proposals. National policy development is being viewed by the Department as a process for recognizing national problems, narrowing differences, and setting reasonable goals. It is a process also for informing the national constituency about the nature and structure of the energy sector – its architecture, its productivity, and most importantly, the critical role it plays in assuring personal and societal well being.

What is emerging from this process is knowledge of energy conditions – regional, local, industry-specific. Also emerging is understanding, which will hopefully remain in our national consciousness, that trade-offs are always required in the making of national policy; and that these trade-offs have a direct and immediate economic impact – sometimes positive, other times not – on some very specific constituency.

NES OBJECTIVES

One of the things that a supportable energy strategy will have to do is to be persuasive in the view that energy policy is not, and cannot be, the exclusive domain of the Federal Government. This is not to say that the Federal Government does not have a central role to play. It is merely to point out that virtually every American, every level of government, and every private and corporate consumer makes energy choices. The Federal Government does influence those choices through research and development, tax policy, and regulations. But vast discretion remains – to producers and users of energy – to be more or less efficient, to respect or disrespect the environment, to be technologically and scientifically competitive or not.

Take energy conservation and efficiency as an example. The analytical evidence suggests that three key elements are at play when energy conservation takes place. These are: technology, price, and behavior. To further refine the example, again the analytical evidence suggests that the greatest potential for conservation exists in the buildings sector. Building shells can be made far more energy efficient than they are currently. Ballasted fluorescent bulbs could replace incandescent bulbs and save large numbers of kilowatts. Windows, doors, air conditioners, heaters, refrigerators, microwave ovens, all could be substantially improved. Actually, the technology is already available to do all of these things. But to capture this energy efficiency, a very large number of very diverse players must make decisions. They must make these decisions individually and collectively. All the decisions will have a price that some people will have to bear directly. Others will view it as external to their interests. It should be self-evident that this price is always paid – either by the decision-maker or by society.

Each of the actors must find it in their interest to produce and use energy in the most effective possible way. The Federal Government can and should contribute constructively to this process by identifying, objectively assessing, and finally removing barriers to effective behavior. Like all nations we have accumulated laws, regulations and policies that have shaped our economy in ways we no longer desire. We chose, for example, the unparalleled freedom provided by a personal vehicle and let public transit wither. We chose the cheap and convenient delivery of goods by truck and reduced our dependence on rail. We built commerce and industry around quick and economical air transportation.

The system we selected provided benefits. It also provided consequences that we have often preferred to ignore. The system now produces problems that will simply have to be resolved.

If we want to make changes to the choices we made over the last 100 years, we must recognize the magnitude of the structure we wish to change. We have, for example, a vehicle fleet, in the U.S., of 170 million vehicles. Changes to even a fraction of this fleet require herculean efforts; they require new technology, internalization of new costs; and, they require change in behavior. These changes will not occur by the stroke of the President's pen. They will occur, I believe, upon the achievement of a national consensus to share the pain, absorb the cost, be assured of benefits, while remaining a productive and competitive nation.

A National Energy Strategy should clarify both the opportunities and the limitations that characterize the role of private and public institutions in the energy sector. It should provide guidance for coherent national, and not merely Federal, action. It should reduce waste and focus attention on those issues where intelligent action will provide the best return on investment – the biggest bang for the buck.

Most of all, in my view, the National Energy Strategy should strive to bring private interests into congruence with the public good. It should chart the course, encourage responsible action, demonstrate leadership, and have faith in the American people's ability to act in their best interests.

INTERNATIONAL DIMENSIONS OF THE ENVIRONMENTAL PROBLEM

Zdzislaw Kaczmarek
International Institute for Applied Systems Analysis
Laxenburg Austria

ARE WE BENEFICIARIES OR THE VICTIMS?

In TIME magazine of October 16, 1989, Robert Redford published a letter to the next generations asking questions that may serve as a motto to my address:

> "I may be the beginning of a generation that wonders: Are we the beneficiaries of our progress and development, or the victims . . . In my opinion, this great dilemma that stares at us, from the approaching year 2000, points out two essential needs: Visionary leadership and long-range planning."

Before coming to the main subject I would like to say a few words about the origin and activities of the International Institute for Applied Systems Analysis (IIASA). It was created as a result of a political initiative of Johnson and Kosygin to organize an East-West research forum where scientists from various countries could work together on problems of global or universal interest. The energy crisis and escalating environmental issues set the majority of IIASA's agenda for the first decade of its existence. Those topics plus the theoretical aspects of systems approach and modeling of complex systems maintained a high interest until the 80s. In order to assure a non-political character as much as possible, the Institute was constituted as a non-profit corporation, whose governing bodies are Academies of Science or other scientific organizations designated by each country to represent their scientific communities.

It should not be surprising that my talk will largely correspond to the approaches and conclusions of IIASA's Environment Program. These are a result of a joint effort by a large number of researchers from many countries, working at IIASA or in a network of collaborating institutes. This Program concentrates on the interaction of various human development activities and the environment, is policy-oriented, interdisciplinary and international in scope. It encompasses long-time horizons and large space-scales, and assumes that environmental discontinuities and surprises may happen.

The growing demand for resources, goods and services by an increasing global population is the primary driving factor in the development-environment interaction. Buy my colleagues from the IIASA Biosphere Project are right in saying that most of the large-scale environmental impacts result not from the people per se but from what people are doing. In this connection of particular importance are the impacts of energy and agricultural production, and some of these impacts are of regional and global character. I share the opinion of many environmentalists that the emerging environmental problems will be increasingly linked with global-scale human activities. During my talk I would like to present some recent results of the IIASA global studies rather than concentrate on possible scenarios of the future European environment and conclude with general remarks on research problems in the presence of environmental uncertainties.

DEVELOPMENT AND ENVIRONMENTAL SUSTAINABILITY

At the beginning of this century an eminent Russian scientist Vladimir Vernadsky was probably the first to point out explicitly the necessity for guided development of the biosphere. His essential message was that either further development of our planet be guided by human intellect, or civilization will disappear from its surface. Seventy-five years later, in the broadly publicized report called "Our Common Future," the UN World Commission on Environment and Development sets up sustainable development as an objective for the world community and for individual nations. This means development that meets the needs of the present without compromising the ability of future generations to meet their needs.

The Commission emphasized that the natural resource base is threatened by climatic change, depletion of the ozone layer, air and water pollution, soil degradation, deforestation and desertification. These are global hazards. No nation can protect itself from them and no nation can solve them alone. A significant proportion of environmental problems is of global character or due to pollution from other countries. The challenges we face can only be solved by joint efforts, internationally and nationally.

As said before, population growth is one of the driving forces in long-term, large-scale interactions between socio-economic development and the natural environment. Projections of future population growth require a good causal theory of demographic changes. This is not easy to develop. Professor Nathan Keyfitz, leader of the IIASA Population Program, points out that most of the existing theories has been developed by observing the past and concludes that one is left with no clear explanation on which to build a good behavioral model to predict future population changes. Nevertheless, such projections are made using various kinds of statistical and quasi-causal models. Two such models have been developed; one by Keyfitz and his colleagues at the Oak Ridge Associated Universities and another by the UN Department of International Economic and Social Affairs, are given. The Keyfitz projections seem to be attractive to environmental studies as they are reasonably well documented, and were used in a number of energy and agriculture studies. The conclusions derived from this model are that the developed world population to the year 2000 and beyond has been to be leveling off and approaching stationarity. The less developed regions will contribute the overwhelming majority of people to the future population. It should be remembered that such massive changes in the concentration of the world population will be associated with severe environmental stresses, and with increased competition for scarce resources, in particular for land and water resources.

The foreseen growth of world population and necessary improvements of living conditions in many regions are closely linked with the economic growth, increased energy production, better food and water supplies. All these should be brought within limits that the global ecosystems can support. In my opinion, the fashionable concept of "sustainable development" does not mean that the development should be stopped, but rather that economic growth must respect natural limits. In such a sense, sustainable development is primarily meaningful in a global context. The international community will therefore need a common analysis of the problems facing us, and a common perception of how the challenges should be met.

ENERGY-ECOLOGY: THE CRITICAL LINK

> "The link between energy and ecology, which is at the root of global climate change, acid rain, forest dieback, and several other major environmental problems are forcing a complete rethinking of our approach to technological, economic and social development, has emerged as one of the most pressing international issues on both research and policy agendas."

These words of Dr. Robert H. Pry, Director, International Institute for Applied Systems Analysis (Options, IIASA, June 1989), may be understood as IIASA's approach to the interconnections between energy use and the biophysical environment. It is obvious that the use of energy is central to most human activities and is one of the determinants of our standard of living. Most of the known projections predict a substantial increase of energy production in the world for the next 40-60 years, although they differ substantially on the future of energy options. In a recently published report (IIASA Research Report 89-4, editors Ferenc L. Toth et al., 1989) a group of IIASA scholars tried to formulate a general approach to the scientific analysis of environmental consequences of energy production. A set of most vulnerable "Valued Environmental Components" (VEC) that can be affected by energy production has been proposed. The output of several energy prediction models was later related to the respective VECs in order to investigate alternative environmental-oriented energy scenarios. The results of the study are rather qualitative and for several reasons need further discussions. One of the conclusions is that the environment was not, in general, an area of primary concern for the past energy studies. There is a need for a deeper analysis of the environmental impacts connected with possible energy futures. We should use the knowledge we have, however uncertain it may be, to manage energy-environment interactions. Up to now, rather trivial conclusions may be drawn: (a) there is a need for energy conservation, first of all in the developed countries, (b) through a fuel-mix evolution the emission of sulfur and CO2 should be reduced, (c) development of renewable energy sources, including direct solar, wind, hydro, and biomass technologies should be promoted. New global and national energy strategies are needed to recognize these issues.

Among other factors highly influencing our environment, increasing demand for water should be mentioned. Because this is my field of activity, it would be strange if I would not present my opinion on global and regional water issues and their relations to development and environment. Fortunately, on a global scale there is enough water to support current and anticipated populations on a sustainable basis. There are however regions and even nations that have experienced, or will experience in a not too distant future serious problems of providing safe drinking water for the population, and/or of meeting industrial and agricultural water demands. To cope with such deficiencies it may be necessary to develop expensive and sometimes environmentally sensitive systems, e.g., large storage reservoirs, canals for transferring water from one river basin to another etc. One of the recent changes in this field is the broadening scope of water management. Added to the conventional tasks of protecting against floods, droughts and erosion, ensuring drinking water supply, and improving water quality, there is now the task of maintaining and restoring the natural state of water resources. The underlying principle that aquatic ecosystems should be protected in their natural state is embedded in many of the new water acts and consolidated water legislation of recent years. Such a policy, however, may be very difficult to implement in most developing countries due to high rate of population growth and lack of money for capital investments.

Population growth, increased demand for energy, food and water, industrialization and urbanization - all these factors highly influence the natural environment on local, regional and even global scale. The results are known: water and air pollution, soil degradation, forests dieback, depletion of the ozone layer and the greenhouse effect. In addition, there may be serious feedbacks that can impose important constraints on the input side of the global and national economies. Focusing, for example, on the agricultural component of economic development, we may be concerned with two questions:

> What are the implications of foreseen agricultural development for the environment?
>
> and,
>
> What consequences might global climatic changes and/or degradation of the environment and the resource base have on the future of agriculture?

Similar questions may be asked in connection with energy production, water management, etc. Unfortunately, very few development models have explicitly addressed such feedback relations. This opens an interesting area for future research.

TOWARD GLOBAL ENVIRONMENTAL SECURITY

It is clear that environmental hazards add a new dimension to the old concept of insecurity at national, regional and world-wide level. In the WCED Report we may read:

> "The whole notion of security as traditionally understood – in terms of political and military threats to national sovereignty – must be expanded to include the growing impacts of environmental stress – locally, nationally, regionally, and globally . . . Certain aspects of the issues of peace and security bear directly upon the concept of sustainable development."

It is clear that national environmental security is primarily the responsibility of the concerned nation. However, countries within the same eco-geographic region share resources of river basins, lakes, seas, mountain ranges, etc. Within such a common part of the biosphere, shared by more than one country, the unilateral development of resources or discharge of polluting effluents will form a threat to the national security of partner countries. This may favor citizens of one country and disfavor those of the others and thus may cause political stress within the region. Environmental problems in Europe, which will be discussed later, constitute convincing examples of such environmental situations.

The interconnectedness and reciprocal dependence of environmental and security issues may be readily illustrated by the fact that hazards are spread transnationally and sometimes globally by natural processes, such as long-distance air and water movement. For example, loss of genetic resources may jeopardize future improvement of crop plants and livestock animals on a global scale. Depletion of tropical forests and woodlands, desertification, increase of greenhouse gases in the atmosphere, and other forms of degradation assume a world-wide extent or have global impact that may affect several attributes of the biosphere.

We come to the conclusion that sustainable development and environmental security are important elements of the general concept of a new international order. But environmental policy - as every policy - should be realistic and free from all illusions. For example:

> In most cases it is not possible to eliminate completely the risk of environmental threats; it is however possible to reduce the risk through wise management.
>
> There is no such environmental policy that can assure the absolute sustainability of resources; what we can do in reality, is to increase the rationality of their exploration and use.
>
> There is no way to avoid uncertainties in planning and/or operating of large environmental systems (water resource systems may be a good example); but by the rational development and operation of such systems we may make them more reliable and thus reduce the level of uncertainty.

Probably the most important condition for creating a realistic environmental policy at the national and international level is the integration of environmental and economic issues in a single decision-making process. The ability to predict and prevent damage to the natural environment is dependent on simultaneous evaluation of the economic and ecological consequences of policies.

FROM THE EUROPEAN PERSPECTIVE

Europe with its 30 countries, relatively high density of population, high per capita income and long history of industrialization is facing serious environmental problems. Possible negative environmental feedbacks on European economy and increasing public awareness are contributing decisively to the fact that environmental issues are today among the most central questions on the agenda of European governments and political forces. This continent also may illustrate a need for international cooperation in solving environmental dilemma. Most of the large river basins are shared by several countries. Because of the prevailing wind directions, some of the European countries are particularly vulnerable to long range air pollution from other nations. For example, about 90 per cent of the acid precipitation in Norway is due to emissions from outside.

A single European nation cannot on its own contribute significantly to a solution of environmental problems on global and regional scales. For example, only binding global cooperation, which includes the largest countries, will be able to maintain the energy balance of the atmosphere. This was a background for a meeting of 24 European heads of state and government in the Hague on March 11, 1989, which gave its support to a declaration setting new standards for international cooperation on environment and development. European countries initiated a number of international agreements on the environment, including the 1979 ECE Convention on Long-Range Transboundary Air Pollution, the Helsinki Convention on Protection of the Baltic Sea, the Sofia Protocol on emission of nitrogen oxides.

What can be said about the future of European environment? To answer this question an IIASA study on environmental implications of alternative development scenarios in Europe has been undertaken in 1985 under the leadership of Dr. William M. Stigliani. Four socioeconomic development scenarios entail:

1. Present trends continuing in Europe and elsewhere (slow economic trend and modes results in slowing down environmental changes).
2. High-growth economy in Europe and elsewhere, with limited attention to environmental problems.
3. Environmentally friendly economy in Europe and elsewhere.
4. Environmentally friendly economy in Europe but not elsewhere.

Having no possibility to present all of the interesting study results (see Stigliani 1989), only the six major findings will be cited below.

- Because of the linkages between the European and global environments, sustaining the European environment in the 21st century cannot be fully achieved without sustaining the global environment;

- The continuation of present trends in economic development and environmental protection in Europe and elsewhere is not sufficient to prevent further deterioration of the European environment;

- High economic growth in Europe and elsewhere without adequate environmental protection accompanying such growth will lead to even more severe environmental problems;

- Environment friendly development in Europe offers the hope of mitigating local and regional-scale problems specific to Europe (such as soil acidification or non-point toxins);

- But these actions, in and of themselves, cannot solve problems within Europe stemming from global changes (such as climate induced water resources scarcity, sea level rise, etc.). To accomplish the latter, the rest of the world must also follow environmentally friendly pathways;

- Thus, European nations should do all in their power to enact environmentally friendly development both in Europe and in the rest of the world.

Following these conclusions, a number of policy actions were recommended to the governments, industry and citizen groups as well as to international organizations.

WHAT SHOULD SCIENCE DO?

The analysis of several large-scale, long-term projections show that most futurological studies postulate rather smooth trends or equilibrium conditions in interactions between development and environment. But from past experience we may easily learn that non-linearities, discontinuities and surprises are more the rule than the exception in such interactions. Some such surprises result simply from lack of scientific knowledge on complex natural processes and their interaction with human activities.

In the 1989 Summit Declaration, the heads of state and government of seven major industrial nations urged all countries to give further impetus to scientific research on environmental issues. They also stated that the persisting uncertainty on some of these issues should not unduly delay practical actions.

The role of science in solving environmental issues may be questioned. I think it is very important, because we should be able to foresee our future, relative to the actions we take. One vital task of modern science is to build instruments capable to identify barriers which humankind must not cross in any circumstance.

The scientific basis for environmental sustainability should rely inter alia on the knowledge produced by such international research programs as for instance UNESCO's Man and the Biosphere Program and the ICSU International Geosphere/Biosphere Program.

Let me express the hope that the intensified cooperation by scientists and scientific institutions from different corners of our world will lead to a better understanding of interconnections between environment and development. The IIASA Environment Program is willing to Participate in such concerted activities.

REFERENCES

1. "Our Common Future," Report of the World Commission on Environment and Development, Geneva-New York, 1987.

2. "Options," International Institute for Applied Systems Analysis (IIASA), June 1989, Laxenburg, Austria.

3. Keyfitz, N. et al. (1983) Global population (1975-2075) and labor force (1975-2050). Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tennessee, USA.

4. Haefele, W. et al. (1981) Energy in a finite world. Cambridge, Massachusetts, USA

5. Stigliani, W.M. et al. (1989) Future Environments for Europe: Some Implications of Alternative Development Paths, IIASA Executive Report No. 15.

6. Toth, F.L. et. al. (Eds.) (1989) Scenarios of Socioeconomic Development for Studies of Global Environmental Change: A Critical Review. IIASA Research Report 89-4.

Table 1. Summary Population Data – Medium Scenario

Region	Population (10^6)						
	Keyfitz *et al.*				UN		
	1975	2000	2025	2075	1975	2000	2025
Africa	401	720	-	1200	509	1070	1949
Asia	2256	3602	-	5427	2261	3356	4168
Europe	473	532	-	589	474	513	527
Latin America	324	569	-	905	322	550	787
North America	237	284	-	324	239	298	347
Oceania	21	29	-	39	18	25	32
USSR	255	312	-	360	253	315	367
World	3965	6079	7723	8927	4076	6127	8177

Table 2. Energy Projections

Author	Energy (TW)					
	1975	2000	2025	2050	2075	2100
Edmonds & Reilly	8.3	15.3	23.9	35.7	49.3	70.1
WEC high	8.7	16.8	27.3	-	-	-
WEC low	9.1	14.4	19.8	-	-	-
Nordhaus & Yohe	8.7	12.5	24.5	32.9	43.3	57.9
IIASA high	8.2	16.8	32.5	-	-	-
IIASA low	8.2	13.6	20.9	-	-	-

II. URBAN POLLUTION

BASELINE AIR QUALITY FOR NORTHEASTERN ILLINOIS

Michael J. Hayes, Manager
Division of Air Pollution Control
Illinois Environmental Protection Agency

Currently, National Ambient Air Quality Standards (NAAQS) exist for six pollutants: particulate matter (PM10), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (03), and lead (Pb). Standards exist for time periods ranging from one hour to one year. One method of establishing baseline air quality and determining compliance with the standards is to normalize the measured pollutant concentrations to the appropriate standard. In this manner, the relative impact of the various pollutants can be readily compared. If the highest concentration site for each pollutant is used, the ratio of the concentrations to the standard will normalize the data. Ratios of 100% or greater indicate the standard is exceeded; whereas ratios of less than 100% indicate the standard is attained. The lower the ratio is below 100%, the less of a problem that pollutant is.

The first figure (at end of the paper) shows the normalized air quality in the Chicago area based on 1988 data. The only two pollutants that exceeded a standard were ozone and particulate matter. Carbon monoxide levels were approximately 90% of the standard, and the other pollutants were well below the standards. Ozone has typically the widest area of impact of all the pollutants. In 1988, over 75% of the monitoring locations in the Chicago area recorded one or more days with ozone concentrations above the standard. Ozone is affected a great deal by the type of meteorology in a particular year. Ozone conducive meteorology was the worst in 1988 in the Chicago area since ozone air quality measurements have been made. As a result, the area of impact and peak concentrations are not representative of a normal year. The particulate matter standard was exceeded at 20% of the monitoring locations. These sites represent the major industrial areas of southeast Chicago and central Cook County.

In order to demonstrate the improvement in air quality in the Chicago area over the last 10 years, a similar normalization was made based on 1979 data for comparison with the 1988 results. The next figure shows the comparison. All of the pollutants except ozone showed improvement; carbon monoxide and nitrogen dioxide went from non-attainment to attainment. The ozone increase was mainly due to 1979 being a more normal year and 1988 being a very abnormally high year. Over the years, lead has shown the most dramatic improvement, going from slightly more than 75% of the standard in 1979 to less than 10% of the standard in 1988.

Putting air quality in the Chicago area in perspective with the rest of the country, the next series of charts compare the air quality in 8 other urban areas with that of Chicago based on 1988 data. Ozone is by far the most widespread problem across the country. All of the urban areas listed exceeded the standard by at least 25%. Also, the number of exceedance days at the worst site ranged from 5 in Detroit to 125 in L. A. Carbon monoxide is the other pollutant where several urban areas exceed the standard and most others have peak concentrations that are at least 75% of the standard. Chicago has among the worst air quality for particulate matter of all the urban areas; however, as was previously noted, the high areas are confined to the heavily industrialized areas. As with Chicago, all of the other urban areas have lead concentrations that are lowest among the criteria pollutants. This a direct result of increasing use of unleaded gasoline in the last several years.

On balance Chicago's air quality compares well with other large urban areas of the country. Most urban pollution problems (carbon monoxide and ozone) are the result of traffic related emissions. Traditional industrial pollutants, particulate matter and sulfur dioxide, have improved a great deal.

CHICAGO
Highest Concentrations as a Percent of the Standard
1988

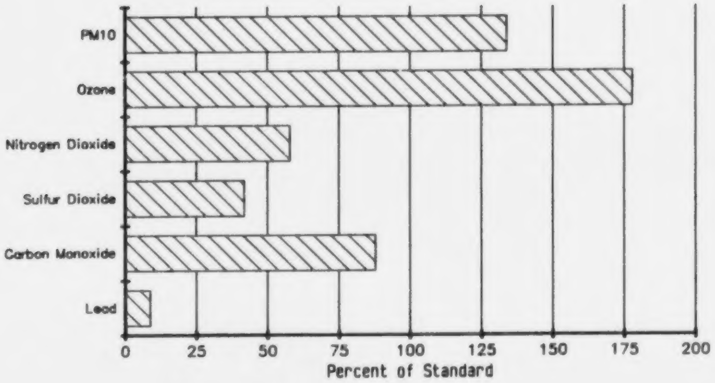


Figure 1

CHICAGO
Comparison of 1979 Concentrations to 1988 Concentrations

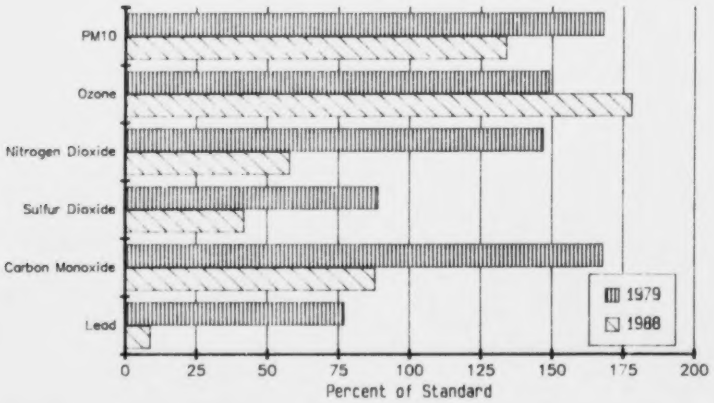
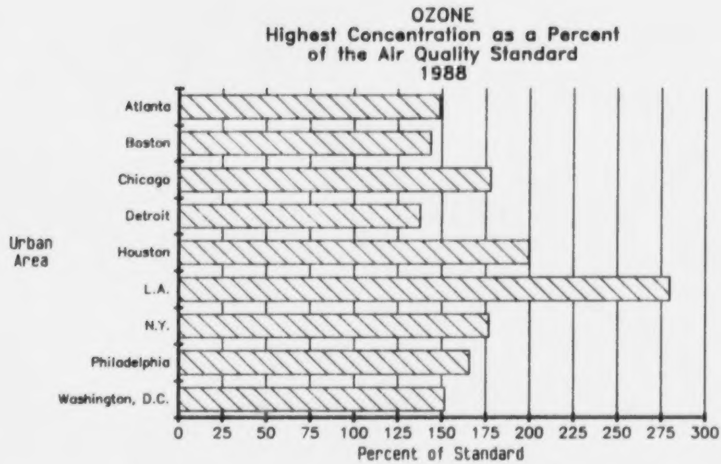
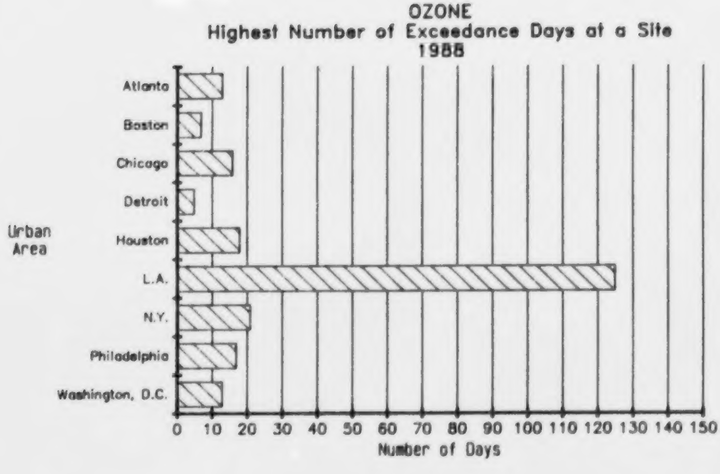


Figure 2



OZONE
Highest Concentration as a Percent
of the Air Quality Standard
1988

Figure 3



OZONE
Highest Number of Exceedance Days at a Site
1988

Figure 4

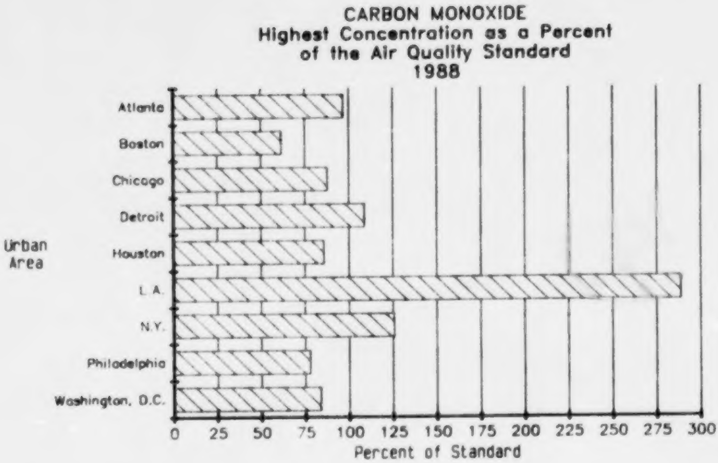

CARBON MONOXIDE
Highest Concentration as a Percent
of the Air Quality Standard
1988

Figure 5

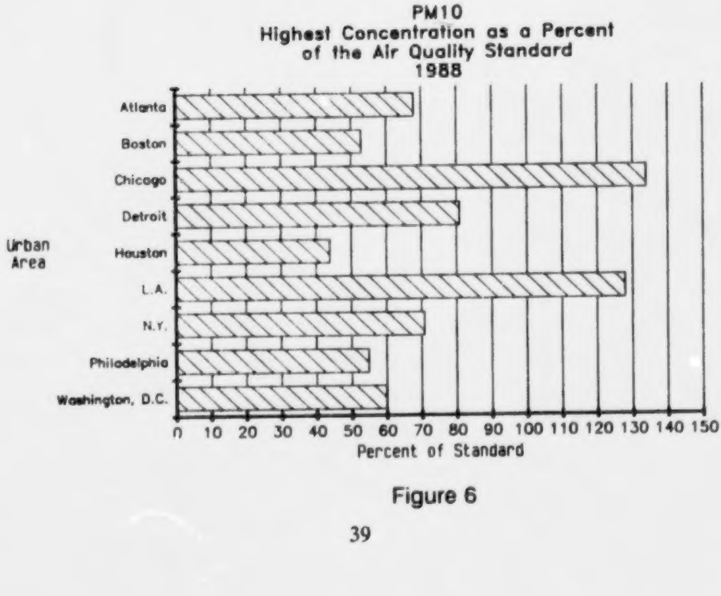

PM10
Highest Concentration as a Percent
of the Air Quality Standard
1988

Figure 6

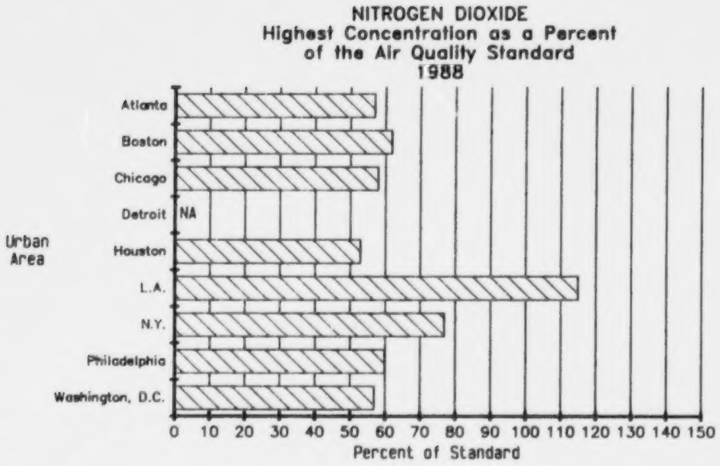


Figure 7

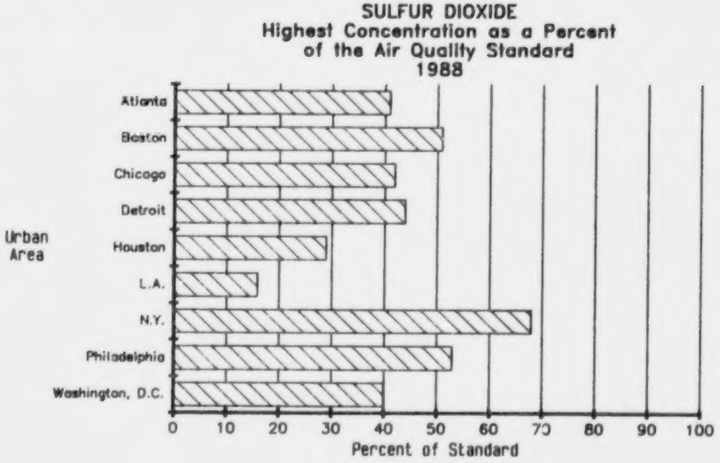


Figure 8

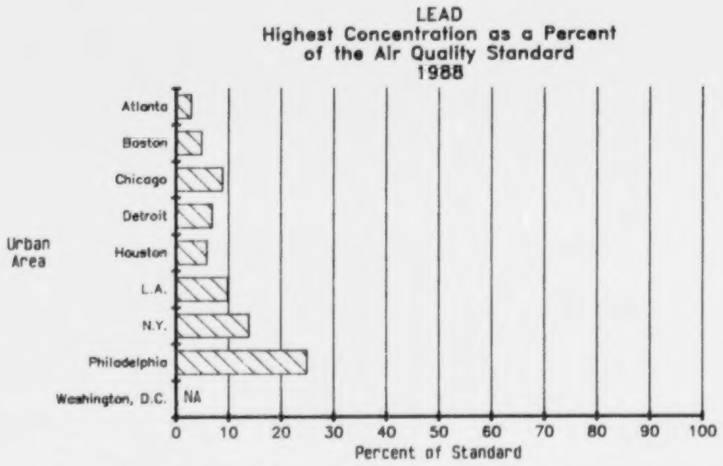

LEAD
Highest Concentration as a Percent
of the Air Quality Standard
1988
Urban Area
Atlanta
Boston
Chicago
Detroit
Houston
L.A.
N.Y.
Philadelphia
Washington, D.C.
NA
0
10
20
30
40
50
60
70
80
90
100
Percent of Standard

Figure 9

UPDATE ON CHICAGO FEDERAL IMPLEMENTATION PLAN

David Kee
Air and Radiation Division
U.S. Environmental Protection Agency

I took special interest in Senator Nelson's comments that newspaper headlines seem to drive our day-to-day concerns. Our Administrator, Bill Riley, was scheduled to make an announcement on an update of a national survey we do each year on radon in the country. He went ahead and made the report public but, because of the earthquake in San Francisco, the radon story did not get very much play in the press. In terms of the comparative risk, in Illinois alone, radon each year results in a number of deaths that would be the equivalent of 20 San Francisco earthquakes. In other words radon is linked to about 1,000 lung cancer deaths in this state each year. I do urge you, if you haven't done so yet, to check your house for radon; it is a relatively inexpensive procedure.

As I looked at the conference agenda, I found it interesting to note the three major topic areas that I am here to discuss today, urban ozone, acid rain, and global warming. Being a federal bureaucrat, a kind of environmental traffic cop if you will, I have to wait until the Congress gives me a speed limit before I can start writing tickets. When I look at where we are in terms of these three major problem areas and how our current position stacks up against the President's proposal on clean air I am impressed with our progress. Urban ozone is a problem that we have been working on for a long time. We have had a regulatory framework and we've had some speed limits in place. We clearly haven't solved the problem, but we have made some inroads because the existing Clean Air Act gives us numerous tools. The President's proposal will for the first time give us some tools to address acid rain. We dealt with SO_2 in the urban setting but we haven't dealt with the huge power plants emitting uncontrolled SO_2 in the high sulfur coal states such as Illinois, Indiana and Ohio. We are waiting for the tools. Global warming is an issue where Congress is still working around the fringes of the issue but as of now, there are no tools proposed. Thus each of the topics of this conference is in a different stage of regulatory development.

I will try to put my discussion into the context of the President's proposal on clean air. The President has three main targets, the first of which is acid rain. The major feature of the proposal is a ten million ton reduction in SO_2 emissions. This reduction is aimed at rural power plants that currently do not have any controls for sulfur dioxide. This is a tremendous step forward in terms of dealing with this problem. Regarding ozone smog, the President's proposal would bring virtually all cities into attainment by the year 2000 except for a relative handful. Chicago happens to be one of those more severe areas where we would have an additional ten years if we needed it. I am going to go into more detail regarding the ozone provisions of the proposed law because I think it is important in terms of the Chicago area Federal Implementation Plan (FIP). While we are struggling with the old law, we also have to consider where the new amendment would take us.

Toxic air emissions, while causing only about one-tenth the health risk of radon, are still a very significant risk factor (2,000 to 2,500 cancers per year nationwide are attributed to toxic air emissions). This is a program that has failed under the current Clean Air Act because we have had to do a case-by-case assessment of risk for each pollutant. We have only controlled eight pollutants out of a list of hundreds that need to be addressed. We need to move away from an "air quality management approach" way of dealing with this problem to a technology approach. Many of us have been saying this for years. The President, in his proposal, has proposed something called, Maximum Achievable Control Technology. This will move us away from the impossible task of dealing with these toxicants on a risk basis.

I now offer a brief overview of the President's Clean Air Act proposal for ozone abatement. The Clean Air Act proposal is a very balanced program that defines federal measures and state responsibilities. The big tension between the federal and state levels, from my perspective, is that States always say they want more freedom to act, but in reality, usually are asking for the federal government to mandate the bottom line program. California is the exception to this rule. The President's proposal would have federal measures to address issues like gasoline volatility, clearly something that should be done nationally, and stage two vapor recovery. If the President's proposal becomes law, stage II vapor recovery will be mandated for the Chicago area. The President's clean fuels program, is an area of controversy. There have been counter proposals offered that would weaken the President's attempt to get clean fuels. Clean fuels, from my perspective, are an essential element in cleaning up Chicago's air. One thing we have been struggling with are the very near term attainment dates in the current Clean Air law. There is virtually no way to clean-up some cities within a three or five years time frame, and you sometimes find environmentalists saying that we should do it in even less time. It is the Los Angeles area, the Chicago area, and the northeast corridor, from Washington to Boston and north into Maine, which are targeted for the severity of the problem and the need for more controls.

In terms of proposed control measures the next steps are incremental. Everybody does the first step and then you keep adding additional requirements. Basically you have to do an inventory of available control technologies and then track regulations. This is not just planning. This is how the traffic cops get some speed limits.

You also will start to see federal requirements in the form of stage two vapor recovery. Two years after the law is adopted, states will have to attain 15 percent reductions. The federal government is not going to tell them how to do this. They will have to look at their situation and make some decisions, given the mix of their industry and sources, and how they are going to do the job. This is an appropriate job for the states, if they are going to have any responsibility under the Clean Air Act. When I start discussing Chicago, you will see that it is relatively easy to come up with a 15 percent reduction level.

Now lets look at the severe non-attainment areas, including Chicago. Basically this requires additional planning beyond 2000. In 2010, a fee of $5,000 per ton would be in place for sources that were still emitting volatile organic compounds. If you failed to meet the attainment dates, this would be a disincentive for emitting after this point in time. There aren't a lot of additional measures for the severe regions; it is mostly doing more planning and tightening up.

Figure 1 shows the time frame for the Chicago FIP. Note the schedule for the Federal Implementation Plan that must have all rules in place by March of 1990. We found that in order to accomplish this we had to do a lot of activities simultaneously. For instance, in the area of control measure evaluation, we had to start evaluating our control measures right away, even before it had decided what emission reductions were needed to achieve the goal. At this point, October 1989, we should be getting close to proposing our Notice of Proposed Rulemaking II, which would be the actual control strategy and putting that out for public comment. As you are aware, there is a settlement agreement between the States of Illinois, Wisconsin and the federal government. We are now waiting to see if the judge will approve that settlement. Such an action could obviate the need to move forward with this next step.

Figure 2 depicts the counties under study. We have examined 11 counties, for the development of this plan. We also looked at areas that were 25 miles beyond the bounds of the study area to pick up additional major sources of organic compound emissions.

Figure 3 is a geographic breakdown of emissions. You can see the State of Illinois contributes 85 percent of the VOC emissions in the study area. Wisconsin has just one percent. This explains why Wisconsin sued Illinois rather than the other way around. Figure 4 breaks down emissions by source type. There are point sources – that are basically industrial sources. There are also area sources that are things like gasoline stations, dry cleaners, the use of architectural coatings; sprays that you have underneath your sink at home; and your deodorant. These are emissions that cannot be associated with a specific address but we know they are out there. Finally, there are mobile sources, primarily the automobile. When you look at the spread, you have about a third of the emissions from point sources, a fourth from area sources, and almost half from mobile sources. So, obviously, if you are going to deal with reducing emissions, you cannot just deal with any one of these source categories. There is no silver bullet for dealing with this problem; you have to address all three areas. There are different issues and problems associated with each category. We determined, through air quality modeling that we needed a 72 percent reduction in emissions. Since our 1988 base year emissions are almost 2,600 tons per day (Figure 5), you would have to reduce to 730 tons per day to attain the standard. As you take on those kinds of reductions, you are also reducing the oxides in nitrogen and carbon monoxide. Thus, with any control strategy you use, you get incidental reductions, even though we have focused on the control of VOC. Because we are getting incidental reductions in these other pollutants, it turns out that instead of having to get down to 72 percent, we only need to get down to 67 percent. That means our target is 860 tons per day. Emissions of 860 tons per day will achieve the health related standard in this 11 county area. Thus far we have proposed a mix of controls that we would use to do this or to get part way down the road.

We need 67 percent, so when you see Figure 6 and look at the column called FIP Reductions, those are the reductions that we would get in the pre-1995 period. These are related to the total emission inventory. Each of these percent reductions is not related to the individual category but to that overall 67 percent reduction. We get 14 percent of our reduction needed from the point sources; we get about 4 percent from the area sources; and 30 percent from the mobile sources. We sum those all up and get about 49 percent reduction and still have about 18 percent shortfall of our target of 67 percent. In accordance with our settlement agreement we will achieve 34 percent reduction in the period between now and 1995. So we are going to get less reduction as part of the trade-off to get the settlement, and you can see where there is a dashed line under "Settlement" – those are controls that we would have required under the Federal Implementation Plan that are not required under the settlement. Illinois will be introducing legislation to tighten its inspection maintenance program. If the Illinois legislative doesn't implement controls then by December 1990, we are committed under the settlement agreement to enforce highway sanctions in the Chicago area. Similarly if Illinois or Indiana fails to address some of the tightening of their existing VOC rules, the federal government is committed to do the job for them.

A major part of what we are going to be doing under the settlement is called a Photochemical Reactive Grid Model (PRGM) as opposed to using an Empirical Kinetic Modeling Approach (EKMA), which is the method used to achieve the 67 percent reduction. It is a very simple, quick model that we could do in the time frame the judge gave us. It will take about 12 million dollars to do this very sophisticated modeling, because, there is a need for a very intensive field study in the summer of 1991. We are talking about having airplanes collect data across the lake; more monitoring; more data analysis; and then a model that will be run on a super computer. Hopefully this will give us better answers to the question of what is happening to ozone pollution in this area.

CHICAGO FIP TIMELINE CHART

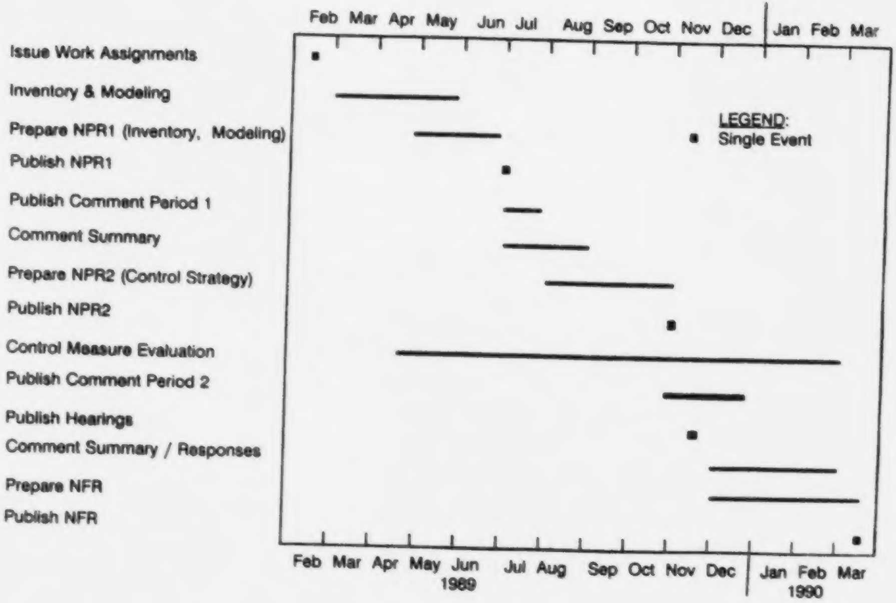


FIGURE 1

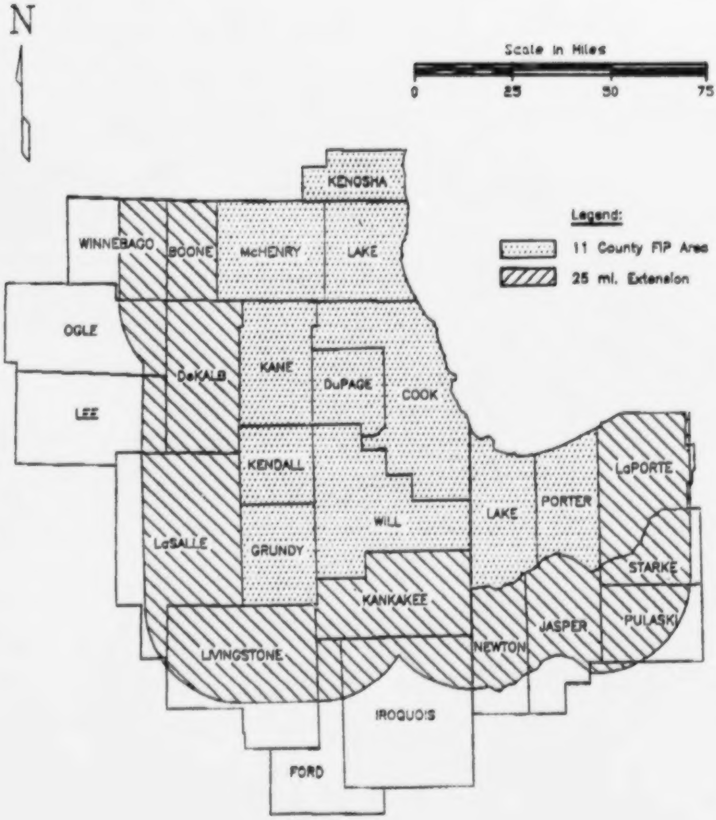


FIGURE 2. Chicago FIP Geographic Area

EMISSIONS DATA FOR CHICAGO CMSA

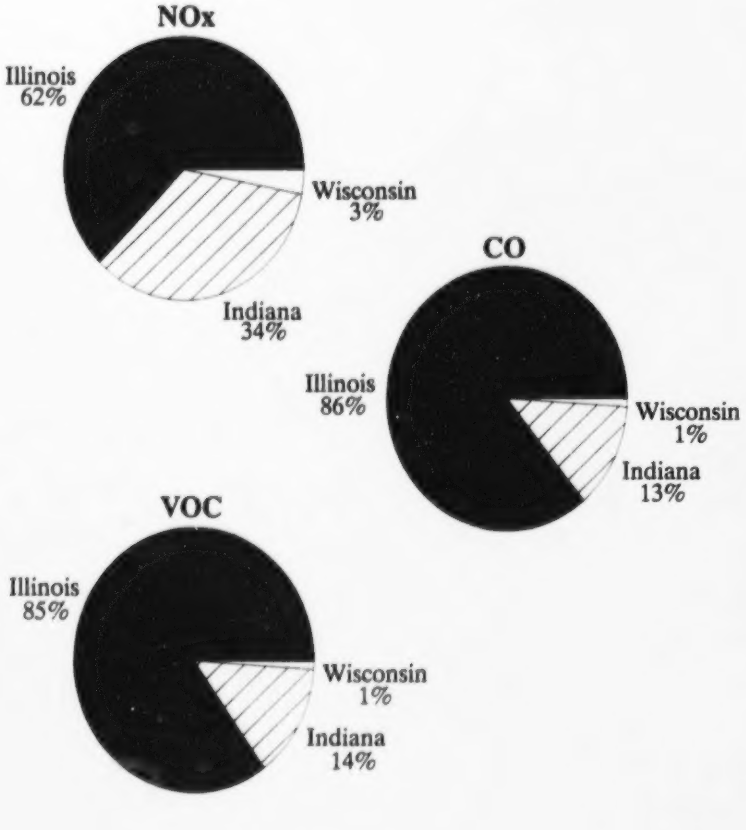


FIGURE 3

EMISSIONS DATA FOR CHICAGO CMSA

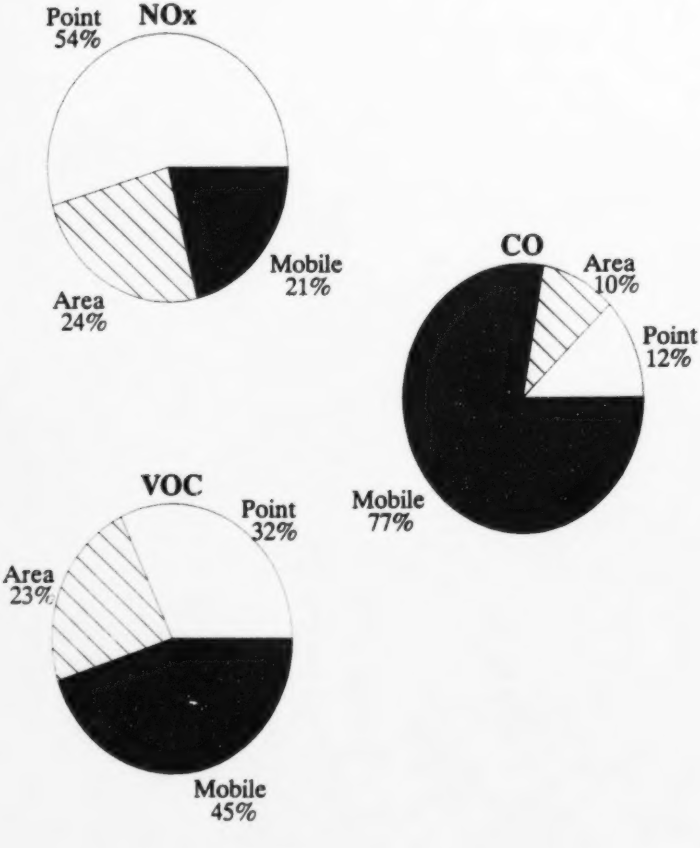


FIGURE 4

CHICAGO FEDERAL IMPLEMENTATION PLAN

CONTROL MEASURE DISCUSSION

BASEYEAR VOC EMISSIONS FOR POINT, AREA, AND MOBILE SOURCES

	EMISSIONS (tpd)				
STATE	POINT	AREA	MOBILE	TOTALS	
ILLINOIS	572	543	1,086	2,200	85%
INDIANA	255	63	55	373	14%
WISCONSIN	5	8	15	28	1%
TOTAL FIP AREA	832	614	1,156	2,600	
	32%	24%	44%		

ATTAINMENT LEVEL VOC EMISSIONS (tpd)

REDUCTION TARGET	72%	67%
ATTAINMENT LEVEL	730	860

NOTE: 72% IS THE VOC REDUCTION TARGET FROM USEPA'S EKMA MODELING.

67% IS THE ADJUSTED VOC REDUCTION TARGET BASED ON THE INCIDENTAL CO AND NOx REDUCTIONS RESULTING FROM IMPLEMENTAION OF THE VOC CONTROL MEASURES.

FIGURE 5

COMPARISON OF PRE-1995 FIP CONTROL MEASURES AND SETTLEMENT AGREEMENT

CATEGORY	FIP Reductions (%)	Settlement Reductions (%)
POINT SOURCES (832 TPD)		
BENZENE NESHAP	4.4	4.4
SURFACE COATING	2.0	-----
MAJOR NON-CIG SOURCES	6.6	-----
VOL STORAGE	1.2	-----
OTHER MEASURES (RACT Fixups)	0.1	0.1
POINT SOURCE SUBTOTAL	14.3	4.5
AREA SOURCES (604 TPD)		
VEHICLE REFUELING (STAGE II)	1.5	-----
ARCH COATING	1.5	-----
AUTO REFINISHING	1.8	-----
OTHER MEASURES	0.3	-----
AREA SOURCE SUBTOTAL	4.1	0
MOBILE SOURCES (1156 TPD)		
FMVCP, CURRENT I/M, RVP 10.5	19.7	19.7
9.0 RVP (IN 1991)	8.6	8.6*
LOWER RVP (IN 1992)	2.1	-----
ENHANCED I/M	-----	0.8
MOBILE SOURCE SUBTOTAL	30.4	29.1
TOTALS 2592 TPD	48.8 (1288 TPD)	33.6 (1702 TPD)

*Expected to promulgated later this year as part of Phase II of the National RVP regulations.

FIGURE 6

THE LOS ANGELES AREA 20-YEAR AIR QUALITY PLAN

Carolyn L. Green
Deputy Executive Officer
South Coast Air Quality
Management District

Since its local adoption on March 17, 1989, the Air Quality Management Plan (AQMP) for the Los Angeles metropolitan area has been the subject of national and even international discussion and debate. Although much of the discussion has focused on the technological challenge and the cost of achieving clean air in Southern California, the plan also has potentially major implications for energy production and use, not only within the region but also throughout the U.S.

My presentation will set forth the air quality problem in Southern California, describe the AQMP, and then focus on the energy-related control measures and the potential energy impacts of the plan. To no one's surprise energy use and air quality are inextricably linked. Unless Los Angeles and other major urban areas examine critically how energy is used and produced, they can never hope to solve their air quality problems.

What is unexpected, at least in the case of Southern California, however, is that even if all sources of combustion – both stationary and mobile source – were eliminated from the air basin, Los Angeles would not meet the ozone standard. Wise use of our energy resources must be an important part of our clean air strategy, but it is only one piece of the puzzle.

The South Coast Air Basin is a 6600-square mile area of alluvial plains bounded on the north, east and south by mountains and on the west by the Pacific Ocean. It is home to over 12 million people, 1 in 25 Americans. The region includes not only City and County of Los angeles, but also Orange and Riverside counties and the westernmost, urbanized portion of San Bernardino County.

Since 1977, the last time the federal Clean Air Act was amended, air quality has improved markedly in the South Coast Air Basin. We have not exceeded the lead standard since 1982, due almost entirely to the phaseout of leaded gasoline. Because we are so dependent on natural gas and very low sulfur fuel oil, we have never violated the sulfur dioxide standard.

Even for those pollutants that are still above federal health-based standards, we have experienced significant improvements. Maximum carbon monoxide levels are down by over 60%, thanks to CO catalysts on cars. This has occurred even in the face of a doubling of auto use. And contrary to popular belief, ozone levels also have declined 15 to 20 percent in spite of a 20 percent population increase. If we look at the number of hours over the ozone standard or at the number of people exposed to unhealthy air, the improvements are even more remarkable.

Unfortunately, the growth we're expecting over the next twenty years will completely wipe out the gains we've made unless Southern California takes additional steps to control emissions. Our regional council of governments estimates that population will increase by approximately 37 percent, two-thirds of which is due to natural increase; employment is expected to jump by some 46 percent; and vehicle miles travelled are expected to increase by a whopping 72 percent.

Against this background, the South Coast Air Quality Management District, the Southern California Association of Governments and the California Air Resources Board spent five years revising the 1982 non-attainment plan for the region. Since 1987 had come and gone without meeting the ozone and CO standards, the regional agencies selected a twenty year attainment time frame as aggressive but achievable.

The AQMP is based on a multi-faceted approach to air pollution control in the South Coast Air Basin. First, all existing stationary sources – large and small – must utilize the best control technologies and management practices available. Secondly, mobile emission must be cut drastically, both through tailpipe controls and through control of transportation demand. Finally, all growth must be offset. Failure to address any of these problem areas will guarantee that the residents of southern California continue to breathe unhealthy air well into the next century.

For ease of public discussion, the AQMP has been organized into three tiers, based on the availability of technology. Tier I calls for "full implementation of known technological applications and effective management practices." Known technology is defined as those measures for which technology is currently available or for which rules and regulations can be adopted within the next five years. This includes expanded use of low-volatility paints and solvents; more stringent controls on fugitive emissions; tighter tailpipe standards for on and off road vehicles; retrofit of power plants and refinery turbines and boilers to reduce NO_x emissions; construction of transit facilities and highway improvements; institution of transportation demand management measures such as ride sharing, telecommuting or modified work weeks; and adoption of energy conservation programs by government agencies.

It is important to note that, unlike the control strategy employed in Chicago and many other urban areas, the South Coast ozone attainment plan depends upon balanced reduction of both ROG and NO_x emissions. The petroleum industry, in particular, had attacked NO_x control as costly and counterproductive. However, our analysis shows that not only is NO_x control needed to meet the NO_2 and PM10 standards, it ensures that the ozone standards can be met throughout the basin. Our analysis has been supported by the California Air Resources and EPA.

Moreover, historical air quality trends data show clearly that ozone levels have dropped farther, faster since the AQMD began regulating NO_x than when it controlled ROG only. Although the focus of the ROG/NO_x debate has been the South Coast AQMP, Los Angeles is not the only region that is exploring the efficacy of a joint ROG/NO_x reduction strategy for ozone attainment. Both Denver and the New England states have publicly supported such an approach. And because of the overwhelming ROG inventory from vegetation, the metropolitan Atlanta air pollution control officials speculate that aggressive control of NO_x emissions may be the only way to attain the ozone standard.

Turning again to the South Coast plan, full implementation of the 123 control measures identified in Tier I would cut ROG and NO_x emissions by almost 60 percent. The region would achieve both the CO and NO_2 standards. PM10 levels would drop by about 40 percent, and ozone levels would be lower by a third. However, the region would not meet federal standards for either pollutant.

Tier II requires "significant advancement of today's technological applications and vigorous regulatory intervention." This includes bringing technologies currently undergoing development into full scale commercial availability; adapting technologies from currently controlled source categories for use by similar uncontrolled industries; achieving a 40 percent clean fuel penetration in the light duty vehicle fleet and 70 percent penetration in the heavy duty fleet; and seeking local government policy and funding commitments to carry out the transportation system improvements called for in the mobility component of the plan. Tier II also contemplates greater use of market incentives such as emission or congestion charges to influence consumer preferences.

Tier II will allow the region to achieve the federal PM10 standard by the turn on the century – mainly through the reduction of secondary NO_x aerosols – and would eliminate the first stage emergency episodes that now occur approximately sixty times per year. As an additional benefit, the Air Quality Management District estimates that today's average 10-mile visibility would increase 70 miles. However, given the population and job growth forecast for the region, we cannot meet the ozone standard without a breakthrough in technology.

Tier III commits Southern California to an aggressive research and development program to bring about the needed technological innovations in time to meet the twenty year attainment time frame identified in the AQMP and in ongoing Clean Air Act Negotiations. The two major focuses for Tier III research are development of ultra-low emitting vehicles (electric vehicles or equivalent emissions performance) and the virtual elimination of the reactive component of solvents and coatings. The goal of the Tier III program is to reduce ROG emissions by another 50 percent. Achievement of this goal would allow the region to meet the ozone standard by 2007.

The AQMD evaluated the energy impacts of the AQMP by examining five major issues: energy conservation; industrial energy use; transportation; alternative (clean) fuels program; the Tier III electrification scenario; and impacts of the plan on the natural gas and petroleum industries.

Many of the control strategies in the AQMP call for shifting away from fossil fuels to the other, less polluting energy sources. In addition the plan specifically asks local governments to reduce their energy use 15 percent by the year 2000 and another 15 percent by 2010. The plan also recommends changes in energy pricing policies and reinstitution of subsidies for energy conservation and alternate fuels to reduce commercial and residential consumption by 10 percent in 2000 and an additional 15 percent by 2010. As the plan is updated, staff will be examining in more detail the opportunities for additional emissions reduction through a more aggressive energy conservation program and more ambitious solar energy program than currently is contemplated.

Energy use in the industrial sector will be affected both positively and negatively by the AQMP. Particularly if a large proportion of the boilers, heaters and turbines in the region are forced to install selective catalytic reduction systems, they will experience a fuel use penalty. This penalty can be offset in part by use of more efficient equipment or by switching to other fuels. In some cases, existing diesel, oil or natural gas fired equipment may be replaced by electric equipment, which would add to the utility electricity generation load. However, it is still not clear to what extent this would be offset by the fuel savings in the replaced fuel sectors.

Although energy conservation is not the main purpose of the AQMP clean fuel strategy, several of the potential fuels – methanol, compressed natural gas, propane, oxygenated fuels, and fuel cells – may well allow for the diversification of the vehicular fuel supply and thus ease some pressure on petroleum-based fuel supplies and decrease the nation's dependence on foreign oil. However, the region will need to identify sources of these alternative fuels, especially since they may not be able to be produced within the air basin. To the extent that such fuels are imported, other areas will bear some of the energy and air quality costs of Los Angeles' cleanup.

In addition to vehicle fueling, the transportation system called for in the AQMP has important energy implications. The system design in the Regional Mobility Plan includes electrification of major rail line haul routes, the rail mass transit system, ship berthing facilities and from 20 to 100 percent of the light duty vehicle fleet. To the extent that other alternatives become available, such as solar or fuel cell vehicles, the need for electric vehicles could be reduced. AQMD staff has conservatively estimated that electrification of 30 percent of the mass transit system and 20 percent of the vehicle fleet could increase electricity demand over 27,000 GWh per year. This estimate assumes no improvements in efficiency. However, a substantial portion of the vehicle recharging need could be satisfied during off-peak hours.

One on the most controversial features of the AQMP is the Electrification Strategy. Based on the modelling analysis, the plan contemplates the electrification of most industrial processes. This includes such Tier I tactics as replacement of stationary internal combustion and utility engines with electricity. Tier II calls for another 50 percent reduction in emissions from industrial fuel combustion. It is important to note, however, that the AQMP does not mandate the use of electricity. If equivalent reductions can be achieved through other means, such approaches are not only acceptable but strongly encouraged.

This strategy has received considerable criticism – on one side by business interests opposed to such an aggressive plan, and on the other by environmentalists concerned about the plan's potential to encourage the construction of additional power plants. However, based on the AQMD's preliminary analysis and using reasonable conservative estimates on energy conservation/energy efficiency gains, it appears that Southern California needn't achieve clean air at the expense of energy supply and environmental quality elsewhere.

As was noted above, the AQMP calls for only a 15 percent reduction in demand due to energy conservation. This modest target can be achieved through use of solar heating, heat pumps and the best available energy-efficient techniques for residential furnaces and water heaters, commercial lighting and air conditioning. Load management, particularly use of off-peak power to recharge electric vehicles, also can help. Finally, the recently adopted AQMD control rule for reducing power plan NO_x emissions is expected to result in the repowering of many existing in-basin generating units with new combined cycle and fuel cell technology within the next ten years. The net effect of all this is that the AQMP does not appear to require the construction of new power plants outside the region.

The AQMD has established ongoing policy and technical working groups with the state Public Utilities Commission and Energy commission and local utilities to refine further our electrical demand forecasts. At the state level, the legislature had directed both the PUC and the Energy Commissions to make air quality a priority in setting state energy supply and pricing policy.

The final issue examined by the AQMD's environmental impact review process was the plan's effect on Southern California's most commonly used fuels – petroleum and natural gas. Certainly the long term market outlook in the air basin for petroleum based fuels – gasoline, diesel, and fuel oil – is bleak. Unless gasoline vehicles can somehow meet the emissions performance levels needed to attain the various federal standards, it will cease to be a viable fuel in the region. Although AQMD and Air Resources Board scientists do not know today how gasoline vehicles can match the emissions of electric vehicles, we are leaving the door open for innovation. To that end, we are particularly heartened by the recent introduction of a new, cleaner gasoline by the Atlantic Richfield Corporation. Use of the fuel is limited to cars that burn unleaded gas, and it can't perform to the standards of methanol or compressed natural gas. But it is important to give credit where credit is due; ARCO has made an impressive and much needed start in the fuel formulation area.

The other major effect of the plan is its potential impact on the cost of petroleum refining in Southern California and, ultimately, around the country. Such retrofit requirements as SCR on refinery heaters and boilers, similar requirements for gasfired turbines (including congeneration turbines), and emission reduction requirements for fluid catalytic cracking units and coke calcining operations are on the near term horizon in Southern California, and it is a matter of time before they are required as reasonable available control technology (RACT) nationwide. An important debate within our region is whether such controls are worth the cost to the oil companies and whether the necessary emissions reductions can be achieved more quickly and cheaply by controlling other sources. An ancillary question is whether the region should require controls on an industry that may ultimately leave the basin. These issues will undergo considerable debate over the next few years as Tier I of the plan is implemented.

Turning lastly to the natural gas industry, the AQMP means good news and bad news. The bad news is that commercial and residential gas use will at best remain flat over the next twenty years, even in the face of substantial population, housing and job growth. This is due mainly to projected improvements in appliance efficiency, as well as substantial competition in the residential heating market from heat pumps. In addition, the gas industry in Southern California stands to lose most of its small stationary engine market to electricity. The AQMD had defined best available control technology (BACT) for new pumping engines as electricity, and is considering retrofit requirements for existing engines. However, standby generators, which are fueled mostly by diesel, would most likely be switched to natural gas or propane. The good news is that, in greater part, the commercial/industrial market losses to electricity will be offset by increased demand from the electric utilities.

As the above discussion indicates, while energy production and use are an integral part of our air pollution problem, they also are expected to play a pivotal role in its solution. Either air quality can be viewed as a major issue, threatening the very survival of the energy industry or it can be regarded as an exciting challenge. The South Coast AQMP comes down very solidly on the side of challenge and opportunity. The energy industry has a great deal of innovation and technical know-how to contribute to the air quality debate.

The question the industry must answer is whether it is willing to accept that challenge.

III. THE ACID RAIN PROBLEM: IMPLICATIONS FOR THE MIDWEST

PAST, PRESENT, AND FUTURE OF ACID RAIN LEGISLATION

Shelley Fidler
Assistant to Chairman for Policy
House Energy & Power Subcommittee

The topic of my presentation is supposed to be the Past, Present and Future of Acid Rain Legislation. I am not certain that the title is appropriate given the fact that we are talking very much about the present right now. But, let me dig in and talk a little about the past. In the past I was one of the people who represented a legislator who was trying to make the point that acid rain probably was not a problem and if it was a problem that we needed a lot more information. I worked for Congressman Phil Sharp from Indiana; although he felt for many years that Acid Rain Legislation was on its way he recognized that the citizens at least of Indiana were still in the denial stage. In fact, we still have lots of people who basically say "let's wait for NAPAP" and question why Congress is in such a big rush. Whether or not there is good reason to have that point of view, the fact is that Congress is clearly not going to wait any longer. This state of affairs is really a result of three events.

The first and most important is the fact that President Bush has decided to make this one of his most important issues. This has broken the log jam, at least in the Republican Party, and has made it really very much in vogue for Republicans of all stripes to support environmental issues. In fact, there is a group of Republicans here who feel that this provides an opportunity for Republicans to seize the environmental issue from the Democrats and that's an important political component of current developments.

Well, the President decided to propose a bill that basically wiped out every other piece of legislation that's ever been filed on clean air issues. This is of interest because the acid rain provisions are extremely stringent and particularly worrisome to the Midwest. I may be talking to an audience that knows this already, but let me at least go through our perspective on the President's bill and then I would be interested to hear your comments on it.

We are concerned about two factors. One is regional inequities and the other is the employment impact. We feel strongly that the President's bill, which eliminates any requirement for industrials to reduce their pollution and loads the reduction requirements onto electric utilities, puts an unfair burden on nine states. These states include: Missouri, Illinois, Ohio, Indiana, Pennsylvania, Kentucky, West Virginia, Tennessee, and Georgia. What has happened, of course, is that only these states that have high electric utility emitters, are being required to do their own clean-up. In contrast, some states with large industrial emitters are let off scot-free. Our favorite example is Texas, which is sixth in the nation for overall sulfur emissions, first in the nation if you add sulfur and NOx together and yet virtually no reductions are required under the President's bill. This is because most of their emissions are industrial emissions that simply get knocked out. The reason for this regional disparity, of course, is not an environmental imperative but an economic imperative. It is more cost-effective for a large electric utility that burns coal to reduce emissions than it is for most industrial polluters. That is a broad generality but it is the reason behind the regional inequity.

Now from a regional equity point of view we could say that burden sharing or some kind of compensation should be given to those states that are required to do more than their fair share. We also have other concerns, including concerns about the high sulfur coal miners in our midwestern states that will be thrown out of work and the dislocation in the coal market. And those are two related but separable issues that are really very actively under consideration.

The plain truth is that here in Washington there are few cases where you have a straight up or down vote. In this case, we are simply a region of the country that is disadvantaged. If you added up all the other states that seem to do pretty well in this bill it would appear that we would not have the votes for anything. We would have to appeal to the kindness of strangers or to their sense of fairness or else we will have to strike some sort of a deal relating to other issues. Recently there has been some concern on the part of high growth areas of the country which feel that they are very disadvantaged by the trading and allowance provision of the President's bill and by the tax. And I frankly believe that this represents an opportunity for achieving some compromise on acid rain legislation.

I can summarize some of my observations. First of all, I think we'll stick with the ten million ton reduction. I think we will retain a cap on the future growth of emissions. I believe that the legislation will involve some kind of marketable permits and trading of allowances. Quite frankly, I think if we want the administration's support we will attempt to strike a compromise without what Governor Sununu would call a tax. And those are the parameters that we will be working within.

The working group includes two Illinois Congressmen, Ed Madigan and Terry Bruce. This group is working even as we speak to try to design a compromise that would make the President's bill more fair, provide some opportunities for growth in the growth states and at the same time give us in the Midwest and Southeast some help with our emissions reductions. This must be accomplished in an environmentally acceptable way. When we present the proposed legislation on the House floor we do not want environmentalists confronting us with accusations of trying to undermine the Administration's environmental goals.

This particular issue is a classic example of where the environment and energy issues collide. This particular bill may well have serious implications relating to how we generate our electricity, where we buy it, and who produces it. The kind of pollution control available to us and the future role of energy conservation also will be influenced by this legislation. This is a pretty exciting time here in Washington. Nevertheless, I am sorry that I could not be in Chicago to be able to discuss this topic on a face-to-face basis.

ECONOMIC IMPACTS OF ACID RAIN LEGISLATION ON ILLINOIS AND THE MIDWEST

David Baker, Manager
Policy Analysis Section
Illinois Department of Energy
and Natural Resources

INTRODUCTION

Acid rain legislation aims to protect the natural resources and health of our nation and that of our neighbor, Canada. The State of Illinois supports this goal. We are very concerned, however, about how the legislation achieves the goal. Unlike most other states, in Illinois acid rain controls could not only cost the electric ratepayer of the state, but also could severely impact our coal industry and the supporting regional economy. The State of Illinois position on acid rain (which I will describe) reflects deep concern about the economic consequences of legislation. It also recognizes the necessity of acting on the problem of Acid Rain.

First, I want to give a little background on the coal and electric utility industries in Illinois to illustrate why the shape of the legislation is so important to the state. Then I will describe the State's position on what policies acid rain legislation should attempt to achieve, specific strategies for realizing these policies, and finally what the impacts of several of the leading bills are likely to be, and how these impacts relate to the legislation principles we would like to see in a bill.

FACTS ABOUT THE COAL INDUSTRY IN ILLINOIS

- Illinois is second only to Montana in demonstrated reserves of coal (those projected to be economically mineable in the future), and fifth in annual coal production.

- Illinois mines produce approximately 60-65 million tons annually.

- The mine value of annual production is approximately $2 billion and (with multiplier effects) the total contribution to the Illinois economy is nearly $5 billion.

- Direct employment in coal mining as of 1988 is about 13,500: down from 18,000 as of only five years ago.

- Coal mining is concentrated in western and southern Illinois where in the most heavily mined counties it accounts for 25% of employment and 30% of personal income.

- Illinois exports approximately two-thirds of its annual production – to 46 electric generating stations in 13 states.

Missouri and Indiana are our biggest out-of-state customers followed by Georgia and Florida. Seven of the top 10 purchasers of Illinois coal are out of state utilities – Union Electric in Missouri is the single largest customer, purchasing nearly 10 million tons per year. Therefore, these sales are subject to the decisions of these out-of-state customers who may switch to low sulfur coal as an acid rain control strategy.

- The majority of Illinois coal is high in sulfur (with a sulfur content greater than 2.5%), while only 6% is classified as low sulfur.

- Only 14 percent of utility coal sales are to generating stations that are scrubbed. (And thus the remaining 86% could be affected by acid rain legislation.)

The major points are that we sell a lot of coal, most of it is high sulfur coal sold out of state, and that acid rain legislation could result in the loss of these sales with disastrous consequences for communities and businesses in central and southern Illinois.

FACTS ABOUT THE ELECTRIC UTILITY INDUSTRY IN ILLINOIS

- Illinois utilities emitted in 1980 approximately:

  - 1.2 million tons of sulfur dioxide (SO_2)
  - 0.4 million tons of nitrogen oxides (NO_x)

  This makes Illinois fourth in SO_2 emissions behind Ohio, Indiana and Pennsylvania (with approximately 7 percent of total utility emissions nationwide), and fourth in NO_x emissions behind Texas, California, and Ohio. (SO_2 emissions have been reduced somewhat and are now down to about 0.9 million.) Most acid rain bills would require Illinois utilities to reduce SO_2 emissions by about two-thirds, and NO_x emissions by half.

- Of the 59 coal-fired electric generating units in Illinois (excluding small municipal and cooperative), four are scrubbed.

  These are: Duck Creek owned by CILCO, Newton owned by CIPS, Dallman owned by CWLP, and Marion owned by SIPCO.

  Ninteen burn low sulfur coal.

  Most of these are owned by Commonwealth Edison Company and are located in and around the Chicago Metro area where emission standards are more stringent.

- Thirty-six units burn high sulfur coal from the Illinois Basin with no SO_2 or NO_x controls.

- Of the high sulfur units, seven are relatively large units located at the three Illinois plants that are among the top 30 SO_2 emitters in the nation.

  These are: Coffeen plan owned by CIPS, Kincaid Plant owned by CECO, and Baldwin owned by IP. The majority of emission reductions in Illinois will come from these plants.

  Twenty-nine are small to medium sized units that will all be 30 years of age or older by 2000.

  (Sixteen are less than 100 mega-watts in capacity, most of the others are under 20 mega-watts.) These will be expensive to control for the amount of reductions achieved; although some may be good candidates for clean coal technologies.

- About half of the generating units in Illinois are cyclone boilers that are difficult and costly to retrofit for NO_x controls.

Cyclone boilers are a type of boiler designed specifically for low fusion coals such as those found in Illinois. About 1/4th of all cyclone boilers in the world are located in the state. They are nearly 10 times as costly to control for NO_x as other types of boilers. A low NO_x burner on a pulverized coal boiler costs less than $300/ton removed compared with more than $2000/ton removed for post combustion controls on a cyclone boiler.

The points to keep in mind are that Illinois utilities will have to make reductions, that these reductions will be because older plants will need to be retrofitted, and that NO_x controls on cyclone boilers are costly.

ACID RAIN POLICIES

Because of these potential impacts of Acid Rain, the State of Illinois' position on acid rain represents one of supporting reductions but only with measures to mitigate both coal and utility ratepayer impacts. This translates into three priority policies: limiting fuel switching, developing and using clean coal technologies, and providing cost sharing to help finance emission reductions. Such an approach will yield meaningful emission reductions at a cost that we believe is fair and equitable. The State endorses the following strategies that address these priorities.

1. Strategy: Acid Rain should spread the burden of emission reductions among all sources and states or, if the control program concentrates on Midwestern electric utilities, the cost of such a targeted program should be shared nationally, e.g., through a national electricity generation surcharge. The proceeds from any surcharge should be available to utilities to offset the capital costs of controls.

   Rationale: Since acid rain is a national problem of total atmospheric SO_2 and NO_x loadings, reduction requirements should be allocated on the basis of total emissions. If, however, controls are targeted to particular regions based on cost-effectiveness or political considerations, then the costs ought to be shared nationally (broadly).

2. Strategy: Legislation should mandate scrubbing of flue gases at some of the larger electric generating units with high emissions where such technology would be most cost-effective.

   Rationale: As an existing technology, scrubbing could be used to achieve substantial emission reductions in a short period of time, i.e., as the first phase of a control program. Moreover, despite its high cost in absolute terms, scrubbing is a cost-effective technique in certain circumstances when measured on the basis of dollars per ton of SO_2 removed (due to its high removal efficiency). Most importantly, mandatory scrubbing at selected generating stations would preserve high sulfur coal markets.

3. Strategy: Legislation should encourage the development, demonstration, and deployment of innovative technologies.

   Rationale: Development of these technologies will allow the country to continue using a plentiful domestic energy resource in a more environmentally safe manner. In addition, their availability will help to mititgate costs and coal impacts. As such, the clean coal technology program is an investment in the Nation's future environmental and economic well-being.

4. Strategy The control program should provide for trading of emission sources.

Rationale Trading allows for smaller or no emission reductions at some sources in exchange for greater reductions from other sources that are cheaper to control. The net effect is the same amount of reductions at a lower cost. Trading also enables innovative technologies with lower removal efficiencies to be used in conjunction with more traditional approaches to emission control.

5. Strategy legislation should provide credit for permanent emission reductions achieved by any means since 1980 and prior to a control program.

Rationale Many states, including Illinois, have reduced emissions beyond that required by the Clean Air Act. (These reductions are the results of such things as conservation, least-emissions dispatch, precombustion cleaning of fuels, retirement of older/dirtier generating units, fuel switching, and the imposition of local acid rain control program.) Credit for these reductions would encourage, instead of discourage, further reductions prior to acid rain controls.

6. Strategy Legislation should exempt cyclone boilers from NO_x control requirements.

Rationale As I mentioned, NO_x emissions cannot be cheaply or reliably controlled from these boilers and, unless improvements in control technologies for cyclones are forthcoming, it is likely that early retirement will be the only plausible option in the event of acid rain legislation. While exempting these boilers from NO_x controls would greatly benefit states where cyclones are operated, it would only marginally affect the overall control program since NO_x emissions from cyclone boilers represent only an estimated 5% of the total nationwide.

7. Strategy Legislation should provide for a reasonable compliance period for meeting mandated emission reductions.

Rationale A reasonable compliance period would (1) allow for a phase-in of utility rate impacts; (2) provide time for the development, testing, and deployment of clean coal technologies; and (3) enable the coal industry to offset potential market losses by developing new markets.

COMPARISON OF ACID RAIN BILLS

We have analyzed four acid rain control bills currently under discussion in the U. S. House of Representatives - HR 3030 (Dingell/Bush), HR 1470 (Sikorski/ Waxman), HR 3211 (Wise), and HR2909 (Bruce of Illinois). We continue to analyze others in the House and are beginning to look at the Senate bills. In case you are not aware of what these bills are: the Dingell bill is the President's Clean Air package (also introduced in the Senate as S.1490); the Sikorski bill is almost identical to the bills Representatives Sikorski and Waxman have introduced for years; the Wise bill is the United Mine Workers' bill, based on the Mitchell Compromise put together last fall; and Representative Bruce is an Illinois Congressman who was one of the "Group of Nine" that has sought to develop its own compromise clean air legislation.

We evaluated each of the bills in terms of the emission reductions achieved, the compliance costs, rate impact, coal market losses, and overall employment effects. I will briefly compare each bill on each of these and then on how well they match up to our preferred policies.

EMISSIONS REDUCTIONS

The bills are very similar in their emission reduction requirements. Congress seems to have reached a consensus that a 10 million ton SO_2 reduction nationwide is needed and the best way to achieve that is to target the plants with emissions exceeding 1.2 million lbs./mmbtu. This means largely focusing on plants in the Midwest. For Illinois this means reducing SO_2 emissions by 2/3's below current levels, or by about 600,000 tons. The reductions are slightly higher for the President's bill because additional SO_2 reductions are made in lieu of more expensive NO_x reductions. The bill allows trading between the two. (The Sikorki bill reductions are different because it has an earlier compliance date.) The Bruce bill requires slightly lower reductions because reductions are allocated to states on the basis of excess emissions rather than emisison rates - meaning rather than having utilities meet a 1.2 lbs./mmbtu rate they must reduce their tonnage of emissions based on how much they were in excess of 1.2 in a base year, 1980. Therefore, credits are allowed for reductions made since 1980.

The NO_x emission reduction requirements are comparable except for the Sikorski bill. Sikorski would allow the Administrator of USEPA to exempt cyclone boilers from NO_x controls if the technologies are not cost effective. We are assuming they would be exempted. (The other minor differences in tons are due to the trading between SO_2 and NO_x or to varying compliance dates.)

COSTS

In terms of annual control costs, the President's bill and the Mine Workers' bill are nearly identical - about $300 million. The bases for the costs are very different, however. The President's bill emphasizes freedom of choice to keep down the costs of controls. The Wise bill mandates scrubbing at selected plants and provides incentives for clean coal technology through national cost sharing. The net result in costs to Illinois ratepayers is the same. The cost of the Sikorski bill is nearly double, however, because of the high cost of controlling NO_x at cyclone boilers. The cost of the Bruce bill is somewhat lower than the others, in part because the reductions for Illinois utilities are somewhat lower, but also because US DOE would be required to pay for controls at Joppa, an Illinois plant that serves a federal facility in Kentucky.

The rate impacts due to these costs would vary widely across the state. Under the Sikorski bill revenue requirements would increase by an average of 8 percent statewide, but most downstate ratepayers would experience increases of 15-25 percent, because the utilities are highly dependent on high sulfur coal. We have not yet calculated the increases utility by utility for the other bills, but they are roughly half as high – 3.5 to 4 percent average statewide and maybe 7-12 percent for downstate ratepayers.

COAL IMPACT

The bills fall into two groups on their coal impacts. The Dingell and Sikorski bills will greatly reduce sales for Illinois coal because both of them are "freedom of choice" bills and have no effective measures for encouraging use of clean coal technology. The Wise and Bruce bills will have a more moderate impact on the coal industry. The Wise bill combines mandated scrubbing at 20 plants with cost sharing for technological controls (and conservation) to minimize coal impacts. The Bruce bill does not mandate technological use, but it gives Governors the discretion to do so and provides broad-based cost sharing that also encourages use of technological controls.

EMPLOYMENT IMPACT

The employment impacts are similar to the coal impacts in magnitude. The job losses include not only the direct impact on coal employment but also the indirect impacts due to the coal industry losses and due to higher utility rates. The Dingell and Sikorski bills have higher employment impacts because of the significant loss in coal markets. The Sikorski bill is highest of all because it will result in both high coal and high rate impacts. The Wise and Bruce bills will result in fewer job losses, the Bruce bill the fewest because it has both the lowest rate and coal impacts.

Clearly, among the four bills, the Bruce and the Wise bill are the best for Illinois. Not surprisingly, they come closest to matching the policies we said would make a good bill. Both provide for national cost sharing, encourage or (in the first phase of the Wise bill) require technological controls, provide for exempting cyclone boilers from NO_x controls on the basis of costs, allow trading among sources, have reasonable compliance deadlines that allow for phase-in of rate impacts and provide for development of clean coal technology. The Sikorski bill, on the other hand, violates most of the principles for a good bill and could be disastrous for the state. The Administration bill is mixed and perhaps, if broad based cost-sharing were included along with a few other changes, the bill could provide a fair program.

CONCLUSION

In summary, we must solve the acid rain problem. How we solve it is of great concern to Illinois and other states of the Midwest. The nature of the coal and electric utility industries in Illinois make us particularly susceptible to the economic consequences of acid rain controls. We sell a lot of coal, most of it high sulfur coal sold out of state; and these sales are an important part of the local economies in much of Western and Southern Illinois. The electric utilities of the state are high emitters of both SO_2 and NO_x – fourth in the nation – and own a large number of cyclone boilers making controls expensive. The economic impact of acid rain, both on job losses and rate impacts, could be minimized, however, by an approach that includes measure to limit fuel switching, provides for national cost sharing, encourage development and use of clean coal technology, and exempts cyclone boilers from NO_x controls, among other specific policies. Analysis of some of the leading bills shows that in fact such policies can achieve similar emission reductions with much more moderate economic impacts.

FACTS ABOUT THE ELECTRIC UTILITY INDUSTRY IN ILLINOIS

- Illinois utilities emitted in 1980 approximately:
    - 1.2 million tons of sulfur dioxide (SO2)
    - 0.4 million tons of nitrogen oxides (NOx)
- Of the 59 coal-fired electric generating units in Illinois:
    - 4 are scrubbed
    - 19 burn low sulfur coal
    - 36 units burn high sulfur from the Illinois Basin with no SO2 or NOx controls.
- Of the high sulfur units:
    - 7 are relatively large units located at the three Illinois plants which are among the top 30 SO2 emitters in the nation.
    - 29 are small to medium sized units which will all be 30 years of age or older by 2000.
- About half of the units are cyclone boilers, which are difficult and costly to retrofit for NOx controls.

Figure 1

FACTS ABOUT THE COAL INDUSTRY IN ILLINOIS

- Illinois is second only to Montana in demonstrated reserves of coal and fifth in annual coal production.
- Illinois mines produce approximately 60-65 million tons annually.
- The mine value of annual production is approximately $2.0 billion and the total contribution of coal mining to the Illinois economy is nearly $ 5.0 billion.
- Coal mining is concentrated in western and southern Illinois where in the most heavily mined counties it accounts for 25% of employment and 30% of personal income.
- Illinois exports approximately two-thirds of its annual production -- to 46 electric generating stations in 13 states.
- The majority of Illinois coal is high in sulfur, while only 6% is classified as low sulfur.
- Only 14 percent of utility coal sales are to generating stations that are scrubbed.

Figure 2

ILLINOIS UTILITY COAL MARKET

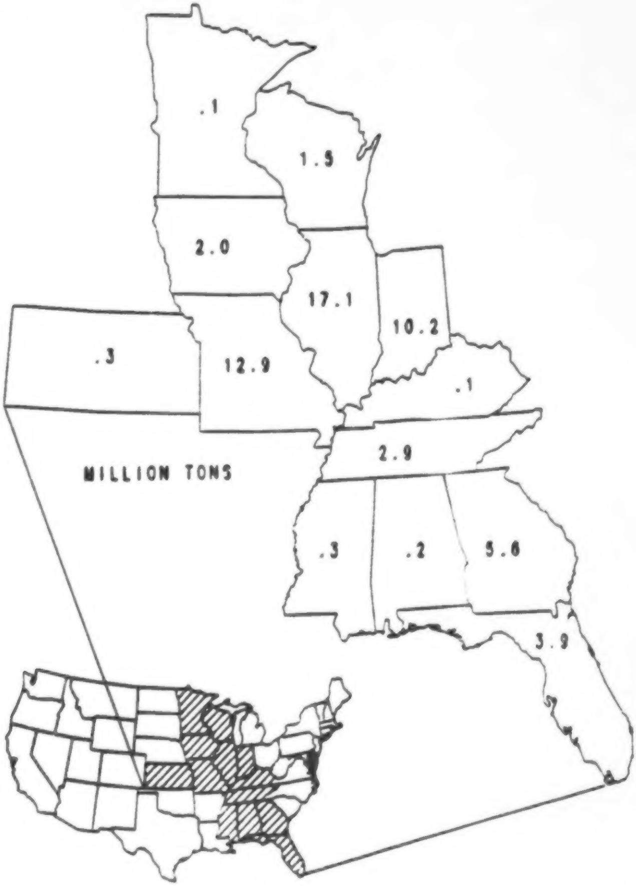


Figure 3

GOAL

Achieve meaningful reductions while minimizing coal and ratepayer impacts

POLICIES

1. Limit fuel switching
2. Develop and use clean coal technologies
3. Provide cost sharing to help finance controls

Figure 4

LEGISLATIVE STRATEGIES

1. Spread the burden of emission reductions or share the costs nationally
2. Mandate scrubbing at selected large plants
3. Encourage the development, demonstration and deployment of innovative technologies
4. Allow for bubbling of emission sources
5. Provide credit for permanent reductions prior to a control program
6. Exempt cyclone boilers from NOx control requirements
7. Provide for a reasonable compliance period

Figure 5

COMPARISON OF ACID RAIN BILLS

Dingell Bill	HR 3030
Sikorski Bill	HR 1470
Wise Bill	HR 3211
Bruce Bill	HR 2909

Figure 6

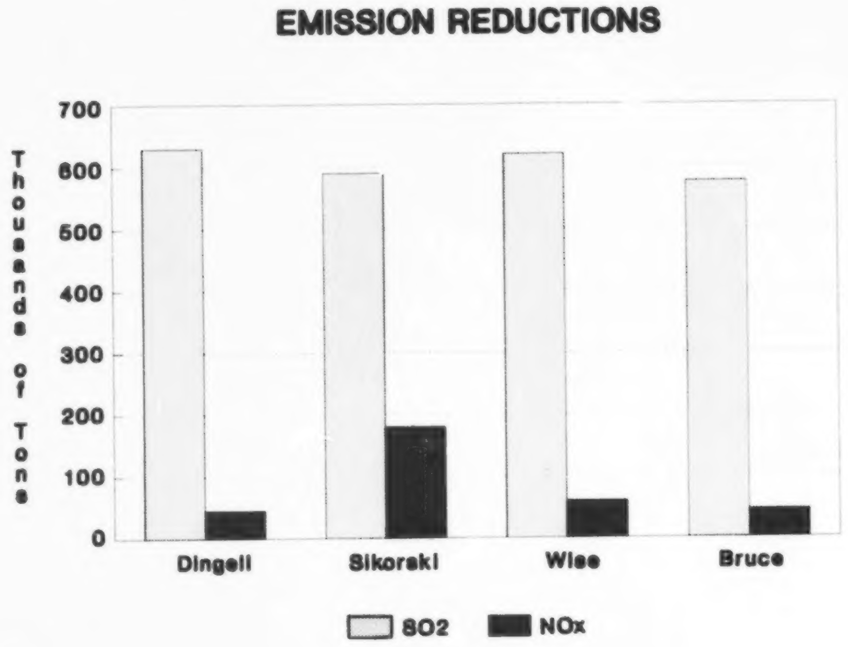
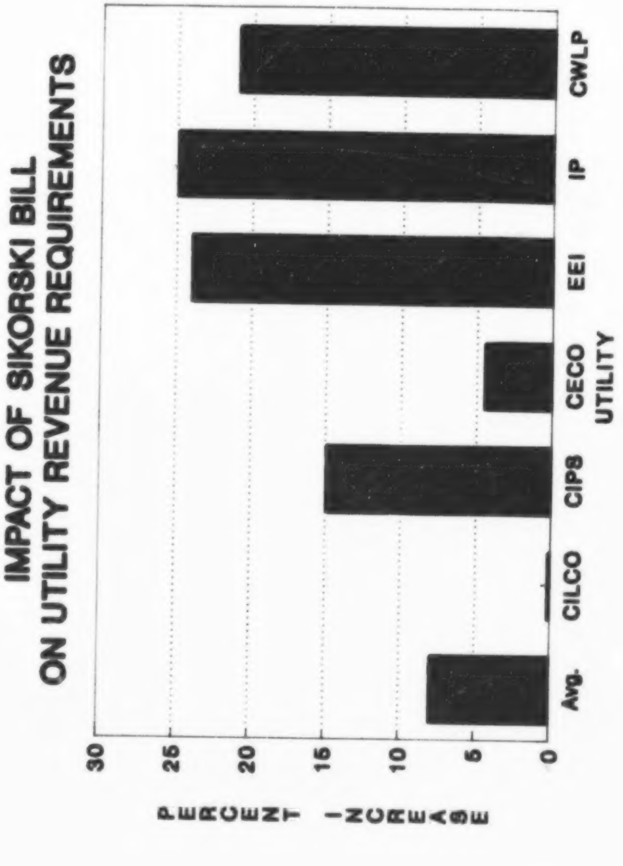
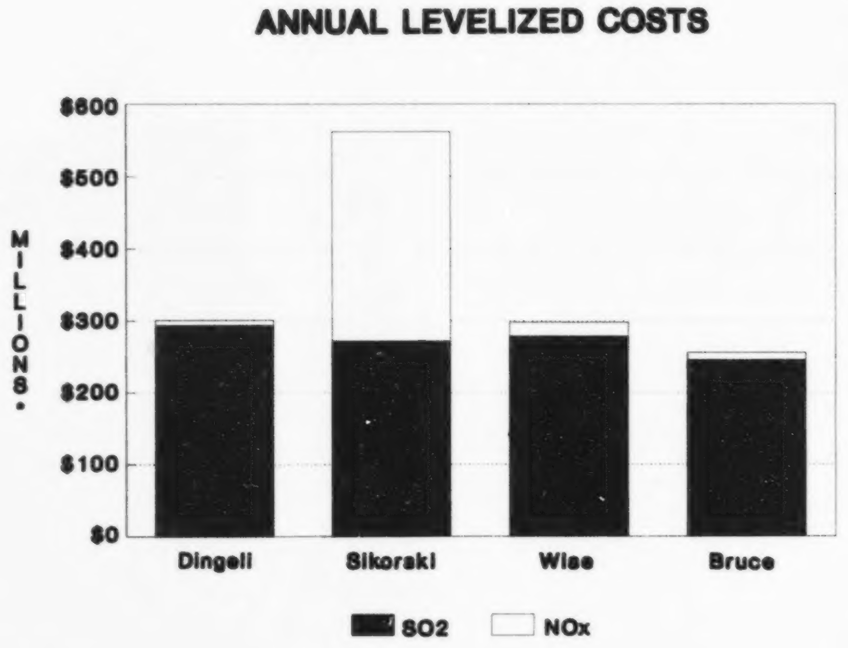

EMISSION REDUCTIONS
Thousands of Tons
700
600
500
400
300
200
100
0
Dingell
Sikorski
Wise
Bruce
SO2
NOx

Figure 7



IMPACT OF SIKORSKI BILL
ON UTILITY REVENUE REQUIREMENTS

Figure 8



ANNUAL LEVELIZED COSTS

*1988 dollars

Figure 9

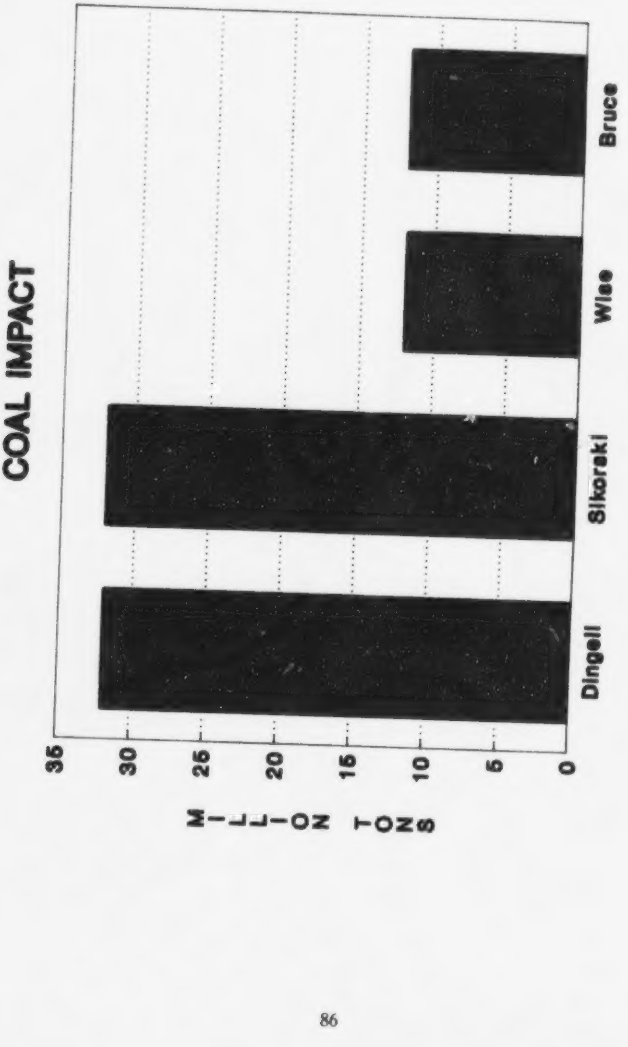

COAL IMPACT
MILLION TONS
35
30
25
20
15
10
5
0
Dingell
Sikorski
Wise
Bruce

Figure 10

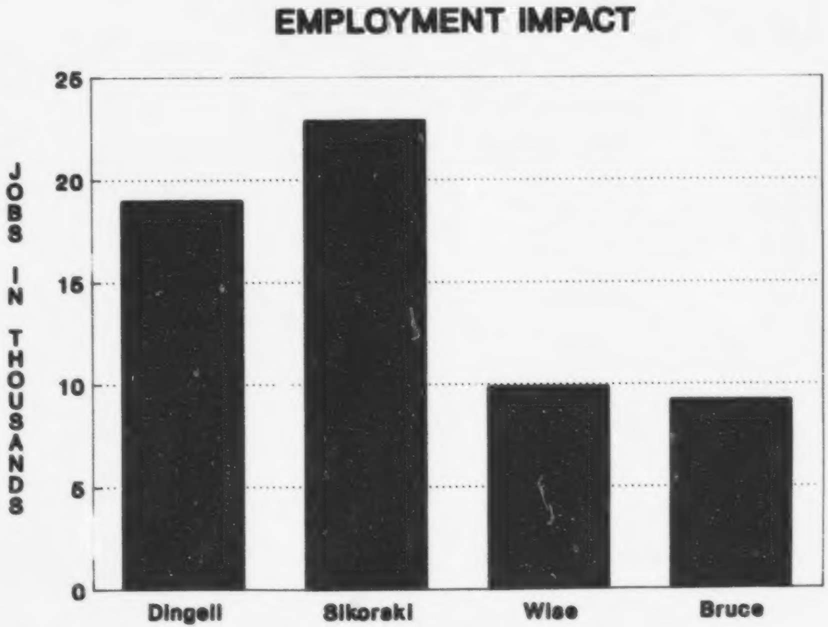

EMPLOYMENT IMPACT
JOBS IN THOUSANDS
25
20
15
10
5
0
Dingell
Sikorski
Wise
Bruce

Figure 11

THE CANADIAN RESPONSE TO THE ACID RAIN PROBLEM

Sherri Watson
Associate Director
Industrial Programs
Conservation and Protection of
Environment Canada

Why are Canadians so concerned about acid rain? First of all, Canada's acid rain problems are not a figment of someone's fertile imagination. After more than a decade of research and thousands of studies, the facts quite literally speak for themselves.

- More than 300,000 lakes in eastern Canada are receiving more acid deposition than they can tolerate; 150,000 lakes are already being damaged; and, 14,000 lakes have been acidified. There is absolutely no question this damage has been caused by acid deposition.
- More than 50 percent of eastern Canada's forests grow in areas receiving unacceptably high levels of acid deposition. While the precise linkages have yet to be irrefutably established, acid rain is clearly one of the causes of forest decline in eastern Canada, the eastern United States and Europe.
- More than 80 percent of Canadians live in areas with high acid rain-related pollution levels. Studies in Canada and the United States have found a strong association between changes in respiratory mortality, in frequency of respiratory problems and in lung function and elevated levels of sulphur dioxide, sulphate and acid aerosols.

If this list of environmental concerns is not enough, the economic concerns are impressive: the damage caused by acid rain in eastern Canada totals about $800 million ($) per year. The natural resource base at risk sustains more than eight percent of Canada's gross national product.

This explains why acid rain is a problem in Canada. But why is it also a bilateral problem? The answer is quite simple - because of the location of major emission sources in the United States, the location of vulnerable areas in eastern Canada and the prevailing weather patterns in eastern North America, mother nature has quite literally put eastern Canada's acid rain sensitive areas at the end of a huge exhaust pipe.

If Canada were to eliminate all of its sulphur dioxide emissions, we would still be eliminating only half of our acid rain problem. About 50 percent of the acid rain falling in eastern Canada is directly manufactured in the United States and exported to Canada. In some areas, the U.S. contribution is responsible for about three quarters of the total acid fallout. This is one area where Canada could do without "free trade." The "balance of payments" is not favorable. In 1980, the United States exported about 4 million tons of sulphur dioxide to eastern Canada, almost as much as our total emissions in the region. Canada, in turn, exported about 1.5 million tons to the northeastern United States.

The other reason it is an important bilateral issue has nothing to do with the environment in a sense. In the minds of many Canadians, acid rain is a bellwether of how well we are doing in our relationship with the United States in general.

In March 1985, Prime Minister Brian Mulroney announced that Canada would implement a comprehensive acid rain control program. The objectives of the program are essentially threefold. First, the Prime Minister recognized that the Canadian house must be in order if we are to expect the United States to take action. Second, Canadian emission reductions will reduce the damage we are doing to ourselves. And, third, Canada has a responsibility to eliminate any damage it is contributing to in the northeastern United States.

Canada set an environmental objective for solving the acid rain problem. Acid fallout (measured as wet sulphate) must be reduced to less than 18 pounds per acre per year (20 kilograms per hectare) in all vulnerable areas.

Our scientists have found that damage to moderately sensitive organisms occurs when the acid rain fallout is above this number; they have also determined that when acid fallout drops below this threshold number that recovery of the environment starts to take place.

We have gone through the calculations to tell us how many tons of sulphur dioxide can be dumped into the atmosphere and from what sources in order to achieve the 18 pound per acre objective. We have concluded two things. First, total annual sulphur dioxide emissions from the Saskatchewan/Manitoba border eastward, must be reduced to 2.3 million tons (about 50 percent of the 1980 level). Second, the transboundary flow of sulphur dioxide

from the United States into eastern Canada must be reduced to about 2 million tons per year (again about 50 percent of the 1980 level).
Canada is well on the way to delivering its part of the bargain. More than 90 percent of the emission reductions required to get down to the 2.3 million ton level are in regulatory or program form and have been formally ratified in federal/provincial agreements. Under the program, these reductions will be achieved by 1994 at the latest. Currently, sulphur dioxide emissions in eastern Canada are about 2.8 million tons - almost 40 percent less than in 1980. Once fully implemented, the program is estimated to cost provincial utilities and the private sector about $425 million ($US) annually or about $15 per capita.

This initative is in addition to existing, highly successful programs under the Canada Clean Air Act of 1971 and complementary provincial legislation that reduced total national emissions by 30 percent by 1980 and achieved stringent air quality standards in Canadian communities.

In looking at the Canadian acid rain control program it is important to realize that the sources of sulphur dioxide emissions in Canada are very different from those in the United States. In eastern Canada, 60 percent of sulphur dioxide emissions come from non-ferrous smelters and about 15 percent from thermal power plants. By contrast in the United States, about 70 percent of sulphur dioxide emissions come from thermal power plants. This means that the nature and scope of actions taken to reduce emissions from sources in the two countries will be quite different.

The Canadian program is designed to let the private sector and provincial utilities choose the most cost-effective means of achieving the required emission reductions. Canadian non-ferrous smelters are using a number of techniques including increasing the rejection of sulphur in their milling operations (a process similar to coal cleaning), converting sulphur dioxide off-gases into sulphur acid (analogous to the use of a scrubber on a power plant), and employing new process technology (analogous to the use of advanced combustion technology). By the time the program is fully implemented emissions from eastern Canadian non-ferrous smelters will be down by more than 60 percent from the 1980 levels.

Canadian utilities will be using scrubbers, low sulphur coal, advanced combustion technology, load management, conservation and alternative primary energy sources to reduce their emissions. Because U.S. acid rain control proposals are often directed at utilities, actions at Canadian utilities often come under scrutiny. The following statistical information should demonstrate the effort eastern Canadian utilities are making to reduce emissions from fossil-fuel-fired generation. In 1980, the average SO emission rate for utilities in eastern Canada was about 3.3 pounds per million BTUs of heat input. By 1995, this rate will be reduced to 1.5 pounds. By the year 2000 it will be about 1.2 pounds and by 2010 it will be about 0.9 pounds. Between 1980 and 2010, fossil-fuel-fired electricity generation in eastern Canada will increase by more than 50 percent. In western Canada, the average SO_2 emission rate will be maintained at about 0.8 pounds through the year 2010.

From our own experience, we know the marriage of technology demonstration and specific emission reduction targets and schedules can produce an acid rain control plan that meets environmental requirements at reasonable costs. Major emission reductions are technically and economically feasible. By focussing technology development on specific emission reduction objectives, we have seen the estimated costs of achieving the necessary reduction drop dramatically in some cases. Technological innovations and plant modernization are both reducing emissions and improving productivity in several industrial sectors. Virtually all of the cost of the program is being borne by the private sector and provincial utilities. Increases in electricity rates are reasonable. For instance, Ontario Hydro, Canada's largest utility, is forecasting a worst-case electricity rate increase of 2.9 percent.

The northeastern United States is benefiting from our actions. We have already reduced the amount of acid rain pollution we export by one third. When our program is completed, we will have cut our exports by more than 50 percent.

As I said earlier we fully and openly acknowledge responsibility for some of the acid rain that falls in the United States. We are taking the actions necessary to reduce this to what we believe are non-damaging levels. We ask nothing more and nothing less than this from the United States.

Stopping the widespread, serious and worsening acid rain damage in Canada now depends on actions in the United States. Yet for the past several years we have been told, even in the face of overwhelming evidence to the contrary, that the issue needs more study, more research and more technology development and demonstration. All of this to avoid taking the actions that are really necessary.

From Canada's perspective, the North American acid rain problem can only be solved through the negotiation of a bilateral accord that requires scheduled emission reductions in both countries, and reduces the flow of U.S. sulphur dioxide into eastern Canada to 2 million tons per year – about 50 percent of the 1980 level.

Canada's objective is based on sound scientific information and existing principles and obligations under international law that both Canada and the United States support. Under international law, States must ensure that activities within their jurisdictions do not cause damage to the environment of other States. This principle is the cornerstone of all international environmental agreements.

Our modelling techniques show that the United States currently dumps, on average, 3.2 million tons; emission forecasts indicate this trend will soon reverse itself unless actions are taken to further manage emissions.

Canada fully acknowledges that how the United States goes about reducing the transboundary pollution flow to 2 million tons is its business. Just as we have done in Canada, Americans must decide how best to cut emissions. Canada's concern is the extent to which transboundary pollution flows will be reduced. Canada will judge all U.S. initiatives against this "bottom line."

In this vein, Canadians were encouraged by President Bush's clean air/acid rain control proposals announced on June 12, 1989. From our perspective, the administration's detailed legislative proposal on acid rain controls appears to be entirely consistent with the President's earlier announcement. The proposal should reduce U.S. transboundary flows of SO_2 to 2.8 million tons beginning in 1996 – a 25% reduction from the 1980 levels – and down to about 1.9 million tons once Phase II is fully implemented. This represents about a 50% reduction and would put U.S. transboundary flows slightly below the 2 million tons necessary to protect the eastern Canadian environment from acid rain-related damage.

We are also encouraged to see that the proposed actions should cap U.S. SO_2 emissions at their reduced level and thus, we believe, cap U.S. transboundary flows at or below the 2 million tonne level.

While the provisions do not explicitly cap U.S. NO_x emissions, they should keep them at or about their current levels by the year 2000. In terms of U.S. transboundary flows of NO_x, the worst case should be no change. Present deposition levels of nitrogen compounds, including those resulting from U.S. transboundary flows are not causing any known acidification damage in Canada; they are, however, contributing to Canada's photochemical "smog" problems.

The emission trading provisions should benefit the Canadian environment. The lowest cost emission reductions appear to be in the Ohio River Valley that is the region that most heavily impacts on Canada. Thus, the emission trading provisions should result in increased emission reductions in the Valley because of straight economics of trading into the Valley.

Analyses we did two years ago concluded that in the absence of regulatory or economic incentives there would be little commercial application of new clean coal technologies before the year 2010. The proposed acid rain legislation would change these assumptions dramatically, but it is too early for us to attempt to quantify the portion of Phase II emission reductions that might be subject to compliance date extensions.

Canada recognizes the realities of the U.S. situation on acid rain; its regional divisiveness and its potential impact on the high sulphur coal industry, to mention just a couple. However, Canadians are encouraged to see that the debate in the United States has largely moved from one of whether acid rain emission reductions are necessary to one of the magnitude and timetable for the reductions and how they should be implemented.

Canada will continue to press its case until this serious problem has been fully resolved. We have been, and we will continue to be, very persistent. I would like to conclude by looking a little further into the future. What are the longer term implications of the major emission reductions necessary to deal with the acid rain problem and the other serious environmental problems we face? Some of you might think of the doom and gloom of the "limits to growth" philosophy. Precisely the opposite is what is required.

In 1987, after four years of investigations and hearings around the world – including Canada – the 22 members of the World Commission on Environment and Development issued their unanimous report entitled "Our Common Future." The Commission, known as the Brundtland Commission after its chairperson, Mrs. Gro Harlem Brundtland, Prime Minister of Norway, called for a new era of economic growth. But growth of an entirely different sort than in the past - growth that sustains and expands the resource base of the planet. Growth that is environmentally sustainable.

So what is this beast, "sustainable development?" For the Brundtland Commission, it meant " . . . meeting the needs of the present generation without compromising the ability of future generations to meet their needs." For Canada's National Task Force on Environment and Economy, it meant "our economic system should be managed to maintain or improve our resource and environmental base." But it also means:

- Living off the earth's interest, not depleting the resource capital of the planet - and investing in the resource base to ensure sustained dividends;

- It means anticipating and preventing environmental degradation;

- It means changing the way we made decisions, and therefore the decisions we make. Consider the polystyrene cup with a useful life of ten minutes and a lifespan of one hundred years; and

- Most important, it means moving environment to the center of decision-making by governments, industry and individuals. It means putting environmental factors alongside conventional economic and social criteria in developing policies, programs and projects. It means making the environment a first-thought, not an afterthought.

IV. GLOBAL WARMING

GLOBAL WARMING: AN OVERVIEW

Kenneth E. Kunkel
Midwestern Climate Center
Illinois State Water Survey

INTRODUCTION

The issue of climate change caused by an increasing concentration of greenhouse gases is one of the most serious environmental issues which society faces. The potential consequences are global in extent and severe in magnitude. This paper provides a perspective on what I believe atmospheric scientists know about the issue and where knowledge is yet limited.

Changes in climatic conditions are a constant feature of our climatic history and occur on all time scales from years, to decades, to centuries, to millennia. An analysis of global temperature records (Hansen and Lebedeff, 1987; Jones et al., 1986) over the last 100 years shows a gradual warming up to about 1940 with slight cooling from 1940 to the 1970s and a warming since then. There is also considerable variability over short time scales that makes it difficult to detect slow trends. Overall, temperatures have varied by less than 1°C over the last 100 years.

These global temperature records suggest to some scientists that global warming due to increasing CO_2 concentrations has already begun because mean temperatures now are about 0.4 - 0.5 C warmer than they were in the late 1900s. Other scientists take an opposing view that, because most of the warming took place from 1880-1940 with little change since then in spite of accelerating increases in atmospheric CO_2 concentrations, the impacts of increasing trace gas concentrations may be much smaller than that predicted by some computer models. My view is that the temperature record is inconclusive in indicating what may happen in the future. Atmospheric scientists do not fully understand the causes of natural variability in the climate system. It is impossible at this time to separate climate changes due to natural processes and those due to human activity.

What is notable about current computer estimates of climate change due to increasing atmospheric trace gas concentrations are their magnitudes and the rapid rate of change. The changes predicted by the models are larger than anything the earth has experienced since the last ice age ended over 10,000 years ago. Since the earth is now already in a relatively warm period, these changes could result in warmer conditions than at any time in at least the last 100,0000 years.

TRACE GAS EMISSIONS

Table 1 (figures and tables at end of this paper) lists the major trace gases that may contribute to future warming and their sources. Carbon dioxide increases are primarily due to fossil fuel combustion and deforestation. Two other important trace gases are chlorofluocarbons and methane. Chlorofluorocarbons are produced for refrigeration, packaging, and as solvents. An important source of methane is in rice production, where it is produced naturally in paddies. Other important trace gases include nitrous and nitrogen oxides and carbon monoxide.

The trace gases listed in Table 1 all have the property that they absorb energy in the infrared portion of the electromagnetic spectrum where the earth emits energy. These gases then reemit some of this energy back to the earth's surface, thereby warming the earth. This so-called "greenhouse effect" results because the earth is basically transparent at wavelengths where our source of energy, the sun, emits yet is semi-opaque at wavelengths where the earth emits, or loses energy. The background concentrations of "greenhouse" gases already result in a significant greenhouse effect and raise the earth's temperature by about 30°C. This is good and necessary for life as we know it. However, increases in these gas concentrations may cause a significant further warming of the earth and disrupt current climate patterns.

Carbon dioxide concentrations have been increasing steadily for the past 100 years. In the middle of the last century, concentrations were about 270 ppm. Figure 1 shows a graph of CO2 measurements taken at Mauna Loa, Hawaii. In just the last 30 years concentrations have increased from about 315 ppm to 350 ppm. They may reach as high as 600 ppm by sometime late in the next century.

METHODS OF ESTIMATING CLIMATE CHANGE

Atmospheric scientists are using several approaches to estimate the effect of increasing gas concentrations on global climate. One approach is to search for a historical period when concentrations were different from today and look at climatic conditions then. Barnola et al. (1987) present an intriguing analysis of Antarctic ice cores (Figure 2) that shows a very good correlation between CO_2 concentrations and mean temperatures for the past 160,000 years. During that period, CO_2 concentrations varied from 180-280 ppm with temperature varying by about 10°C. While such an analysis does not distinguish between cause and effect, these results suggest the plausibility that large climate changes may occur as we change atmospheric trace gas concentrations. One limitation of this type of approach is that past concentrations have not been anywhere nearly as large as projected concentrations for the next century. Therefore, we cannot directly use this information to project the future climate.

GENERAL CIRCULATION MODELS

The principal tool which atmospheric scientists are using to estimate the potential impacts of these increasing gas concentrations on global climate are General Circulation Models or GCM's. These are complex mathematical models solved on computers that attempt to simulate atmospheric circulations in 4 dimensions: 3 spatial dimensions and time. There are only a handful of groups in the world that have actually implemented them. One common scenario used by these modeling groups is to simulate the climate for a doubling of trace gas concentrations over their current levels. We could reach this level of trace gas concentrations sometime in the next century. These models are all consistent in showing a significant global warming. Figure 3 gives the results of three different models (Hansen et al. 1988; Wetherald and Manabe, 1988; Schlesinger and Zhao, 1988) for the United States. The top graph shows the United States' temperature changes to be expected by seasc . and for the year as a whole. All of these models indicate a United States seasonal and annual warming in the range of 3° to 5°C. This is an extremely large change in climate. By way of comparison, summer temperatures in Illinois during the 1988 heat wave averaged only 1° - 2°C above normal. The bottom graph shows the expected changes in precipitation. In general, the models show increases in precipitation on an annual basis and for each season, although one model indicates a decrease in summertime global precipitation.

Table 2 lists some of the general predictions of the GCM's. The first prediction is that there will be a significant cooling of the stratosphere. This appears to be virtually certain with increased trace gas concentrations. This result is due primarily to reduced ozone concentrations and therefore reduced ultraviolet absorption and also to increased infrared emissions because of the increased concentrations of greenhouse gases at that level. The second prediction is that there will be a global mean surface warming. This also appears to be very probable. For most of the models, the range of predictions is about 1.5° - 4.5°. The third prediction is that there will be an increase in global mean precipitation. This also appears to be very probable because the warmer temperatures will result in increased evaporation from oceans and therefore larger supplies of atmospheric water vapor. It also appears very probable that there will be a reduction of sea ice as a result of increased temperatures.

The fifth, sixth, and seventh points in Table 2 address regional climate change issues. The first prediction here is that there will be a significant surface warming during winter in polar regions. This will be the result of reductions in the amount of sea ice that will have two effects: (1) this will cause a decrease in the earth's reflectivity and increased absorption of solar radiation: and (2) there will be an increase in the efficiency of transfer of heat between the polar oceans and the surface above it. The sixth point is that some of the models suggest that the interior of continents will be drier and warmer during the summer than they are present. This will result from an earlier onset of the normal spring to summer reduction of soil moisture. By mid-summer, soil moisture will be limited and much more of the incoming solar radiation will be used to heat the atmosphere rather than evaporate water. This also appears to be likely but is some what more controversial because the models treat surface hydrology in a rather simplified manner. The models also suggest that precipitation will increase at high latitudes. This is the result of the increased poleward penetration of warm moist air.

A final prediction resulting from the GCM's is that there will be a rise in global mean sea levels. This also appears probable primarily because of the thermal expansion of sea water, the result of increased global temperatures. There also may be a contribution due to melting of land ice such as on the Antarctic continent but this is a more controversial issue and is less certain at this point.

There are many factors surrounding this issue about which we are very uncertain. One issue is how will change occur? Figure 4 shows two different possibilities. Will it occur as a slow upward trend in temperature and a gradual change in other climatic features? Or will it occur as a series of steps whereby the temperature of the earth will increase rapidly over a short period of time and then stabilize for some years?

Another important question is how will we know when climate change has begun? This is an extremely difficult question to answer because the normal climate is characterized by high year-to-year variability. Therefore our problem becomes one of detecting the climate change signal in a very noisy background signal. We do not have the answers to this question.

A third significant unknown is the issue of regional climate change. There are significant differences among the models regarding regional conditions in the future. It is extremely important to improve our knowledge of regional climate change is if we are to estimate accurately the impacts.

The models also do not tell us with confidence how climatic extremes may change as the climate changes. Will the frequencies of climatic extremes be greater or less? What about changes in the frequencies of such elements as tornadoes and hail, flash floods, etc.? The models at the moment do not give us any information regarding these types of issues, yet many impacts are in fact related to changes in extreme. As an example, work that has gone on at the Illinois State Water Survey has detected changes in the Midwestern U.S.

over the last 80 years in the frequency of extreme rainfall events (Angel and Huff, 1989). This certainly has major impacts on hydrologic applications. Yet we do not know how this might change in the future.

Since we are basing much of our concern on the results of the GCM's, it is necessary to discuss the limitations of these models and some of the complexities in modeling atmospheric processes. These models are basically computer solutions of a set of mathematical equations. They attempt to predict how the various atmospheric conditions, such as temperature, wind, humidity, pressure, and precipitation change with time. This is done by breaking the earth/atmosphere system into a series of grid points where these atmospheric variables are predicted. The values at these grid points represent the surrounding area. One major problem with these models is that the distance between grid points is large, typically 300 miles or more. This means, for instance, that the entire state of Illinois or several states may be represented as a single point. Even with such crude resolution, the necessity to solve the equations over the entire globe requires huge computing resources and limits the resolution that can be obtained. The crude resolution is one important reason why we have such little confidence in GCM estimates of regional climate change.

There are also many important processes that are now modeled very simplistically or not included in the models at all. In many cases, our knowledge of how to model these processes is quite limited. Many of these can be classified as feedback processes in which the climate system and the process interact in a complex way to reach a new equilibrium state. There are a number of these that may have important effects, as shown in Table 3. For instance, as the earth becomes warmer, it is likely that water vapor concentrations will increase due to increased evaporation. However, water vapor has the same property as CO_2 in that it absorbs in the infrared portion of the spectrum where the earth emits. Therefore, it will serve to amplify the affects of trace gas increases. This is an example of a positive feedback process. Ice and snow cover are in the same category. Since they are highly reflective, a decrease in percent coverage due to warming will cause an increase in the absorption of solar radiation at the surface, again amplifying the effects of trace gas increases. Cloud cover and cloud composition are other important factors because they determine to a large extent how much solar radiation reaches the earth's surface. Yet, we do not know whether a warmer, wetter world will have more or less cloud cover and what the composition of future clouds may be. Model sensitivity studies (Mitchell et al., 1989) indicate that the results of GCM's are very sensitive to how clouds are treated. Ocean circulations are still another very important feedback process. Ocean surface temperatures play an important role in determining atmospheric circulations. Yet, ocean surface circulations are driven in large part by atmospheric circulations. If some recent theories are correct, the El Nino phenomenon is an ocean-atmosphere positive feedback process involving the depth of the ocean thermocline (Barnett et al., 1988). This is an example of the type of interaction that ought to be included in GCM's. Since knowledge of ocean circulations, particularly deep ocean circulations, is even more limited than knowledge of atmospheric processes, this is a potentially large source of error in model results. Oceans also act as a "flywheel" in the climate system. Because of their large effective capacity for storing heat, they may delay the onset of warming. Therefore, it may take years or decades for trace gas emissions to manifest their full warming potential.

POLICY CONSIDERATIONS

There are a variety of policy issues related to this problem. Table 4 shows the percentage contribution to global warming from the various trace gases. Carbon dioxide is the most important but several others make significant contributions. This includes methane chlorofluorocarbons, and nitrous oxides. If we look at the contribution by the economic sector (Table 5) we find that energy is the principal culprit as one might expect. However, agriculture, forestry, and the production of chlorofluorocarbons are other important contributors.

Table 6 shows the contributions by region. The United States is the largest contributor but there are many other countries that make significant contributions including the USSR, the European Economic Community, China, Brazil, and India. This certainly suggest that any solution to this problem will require international cooperation.

The major question facing us as a society is, can we adjust to possible future climate changes or should we try to prevent these changes by reducing trace gas emissions? What would it take to stabilize the situation and prevent increases in concentration of greenhouse gases? Figure 5 shows what kinds of cuts in carbon dioxide emissions would be required to stabilize concentrations at present levels. This indicates that it would require a 75% cut in carbon dioxide emissions to do this. This should suggest to you that extremely painful steps would need to be taken to prevent increasing concentrations of trace gases.

Policy makers are faced with a real dilemma. On one hand, it appears that increasing concentrations of trace gases may cause perhaps disastrous changes in the climate. On the other hand, the stops to prevent this appear to be so painful that it may be politically impossible to convince society to accept these steps. Do we, as a society, begin to act now to prevent this from occurring by taking these painful steps? The problem with prevention is that there is still great uncertainty about how much the climate may change. Or will we rely on our ability to adjust our economic structure to adapt to the new future climate? This latter alternative is difficult because we are not quite sure how the climate may change on a regional scale. In some areas, adjustment may be very costly.

In summary, the scientific treatment of this problem is likely to undergo significant evolution in the next 10-30 years. It is possible, and perhaps even likely that the estimates of future warming may change significantly. However, policy-makers must realize that this is for practical purposes an irreversible process and that it may take decades for the climate system to react fully to present emissions. By the time global warming is detected with certainty, we may have already committed the world to substantial further warming without realistic hope to reversal. It seems prudent to take some mitigating steps now, particularly those that have multiple benefits. As an example, a mandatory increase in automobile fuel efficiency would not only reduce CO_2 emissions. It also would conserve our finite and precious resources of fossil fuels, reduce our dependence on foreign oil reserves, and increase air quality in urban areas by reducing exhaust emissions.

These types of actions can contribute significantly to reductions in trace gas emissions with perhaps only minor costs to society. Even if atmospheric scientists are "wrong," many benefits to society will have been realized.

REFERENCES

Angel, J. and F. Huff, 1989: Climatic fluctuations in midwestern heavy rainstorm distributions. Proceedings of the Sixth Conference on Applied Climatology. American Meteorological Society. Charleston, South Carolina, 7-10 March.

Barnett, T., N. Graham, M. Cane, S. Zebiak, S. Dolan, J. O'Brien, and D. Legler, 1988: On the prediction of the El Nino of 1986-1987. Science, 241, 192-196.

Barnola, J.M., D. Raymond, Y.S. Korotkevich, and C. Lorius, 1987: Vostok ice core provides 160,000 year record of atmospheric CO_2 Nature 32, 408-414.

Conway, T.J., P. Tans, L.S. Waterman, K.W. Thoning, K.A. Masarie, and R.H. Gammon, 1988: Atmospheric carbon dioxide measurements in the remote global troposphere. 1981,-1984. Tellus 40:81-115

Hansen, J., and S. Lebedeff, 1987: Global trends of measured surface air temperature. Journal of Geophysical Research, 92, 345-372.

Hansen, J., I. Fung, A. Lacis, D. Rind, S. Lebedeff, R. Ruedy, and G. Russell, 1988: Global climate changes as forecast by the Goddard Institute for Space Studies three-dimensional model. Journal of Geophysical Research, 93, 9341-9364.

Hansen, J., A. Lacis, D. Rind, G. Russell, P. Stone, I. Fung, R. Ruedy, and J. Lerner, 1984: Analysis of feedback mechanisms. In J. Hansen, and T. Takahashi, eds. Climate Processes and Climate Sensitivity. Geophysical Monograph 29, Maurice Ewing Volume 5. American Geophysical Union, Washington, D.C., 130-163.

Jones, P.D., T. M. Wigley, and P.B. Wright, 1986: Global temperature variation between 1861 and 1984. Nature 322, 430-434.

Komhyr, W.D., R.H. Gammon, T.B. Harris, L.S. Waterman, T.J. Conway, W.R. Taylor, and K.W. Thoning, 1985: Global atmospheric CO_2 distribution and variations from 1968-1982 NOAA/GMCC CO_2 flask sample data. Journal of Geophysical Research 90:5567-5596.

Lashof, D., 1988: The Dynamic Greenhouse: Feedback Processes That May Influence Future Concentrations of Atmospheric Trace Gases. U.S. Environmental Protection Agency, Washington, D.C.

Mitchell, J.F.B., C.A. Senior, and W.J. Ingram, 1989: CO_2 and climate: a missing feedback? Nature, 341, 132-134.

National Academy of Science (NAS), 1987: Current Issues in Atmospheric Change. National Academy Press, Washington, D.C.

NOAA (National Oceanographic and atmospheric Administration), 1987: Geophysical Monitoring for Climatic Change No. 15, Summary report 1986. Schnell, R.C., ed. U.S. Department of Commerce, NOAA Environmental Research Laboratories, Boulder. 155 pp.

Schlesinger, M. and Z. Zhao, 1988: Seasonal climate changes induced by doubled CO_2 as simulated by the Oregon State University atmospheric GCM/Mixed-Layer ocean model. Oregon State University Climate Research Institute Report. Corvallis, Oregon.

Siegenthaler, U., 1983: Uptake of excess CO_2 by an outcrop-diffusion model of the ocean. Journal of Geophysical Research 88:3599-3608.

Wetherald, R.T. and S. Manabe, 1988: Cloud feedback process in a general circulation model. Journal of Atmospheric Sciences, 45, 1397-1415.

Table 1. Major trace gases and sources.

Trace Gas	Sources
Carbon Dioxide (CO_2)	Combustion/Deforestation
Chlorofluorocarbons (CFCs)	Refrigerants/Packaging/ Solvents/Other
Methane (CH_4)	Rice/Wetlands/Livestock/ Tundra/Landfills
Nitrous Oxide (N_2O)	Combustion/Soils/Fertilizer
Nitrogen Oxides (NO_x)	Airplanes/StationaryCombustion/ Transportation
Carbon Monoxide (CO)	Transportation/Biogenic/ Other Combustion

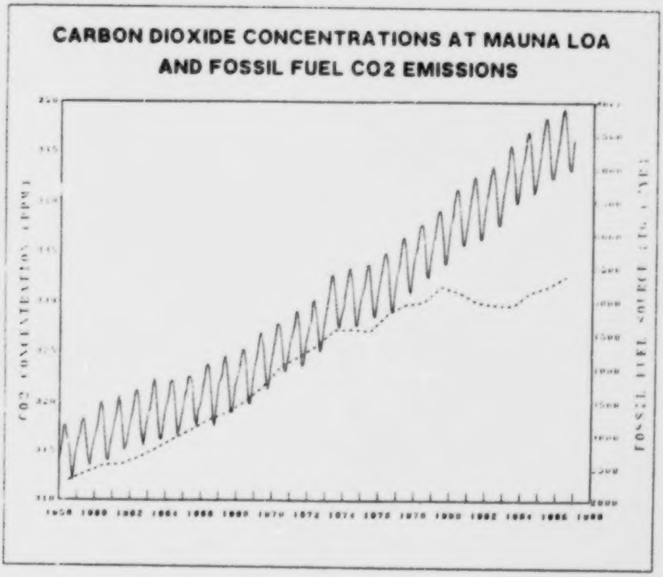


Figure 1. The solid line depicts monthly concentrations of atmospheric CO_2 at Mauna Loa Observatory, Hawaii. The yearly oscillation is explained mainly by the annual cycle of photosynthesis and respiration of plants in the northern hemisphere. The steadily increasing concentration of atmospheric CO_2 at Mauna Loa since the 1950s is caused primarily by the CO_2 inputs from fossil fuel combustion (dashed line). Note that CO_2 concentrations have continued to increase since 1979, despite relatively constant emissions; this is because emissions have remained substantially larger than net removal, which is primarily by ocean uptake. (Sources: Komhyr et al., 1985; NOAA, 1987; Conway et al., 1988).

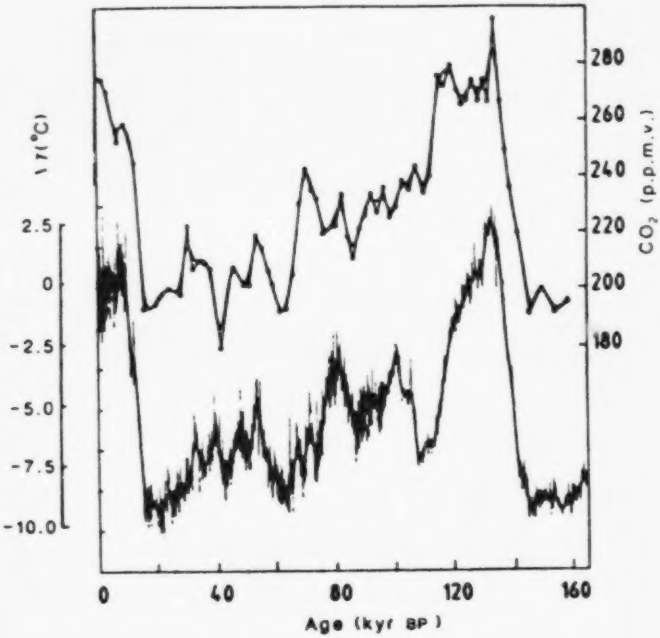


Figure 2. Carbon dioxide levels and temperatures over the last 160,000 years. From Vostok 5 Ice Core. (Source: Barnola et al., 1987).

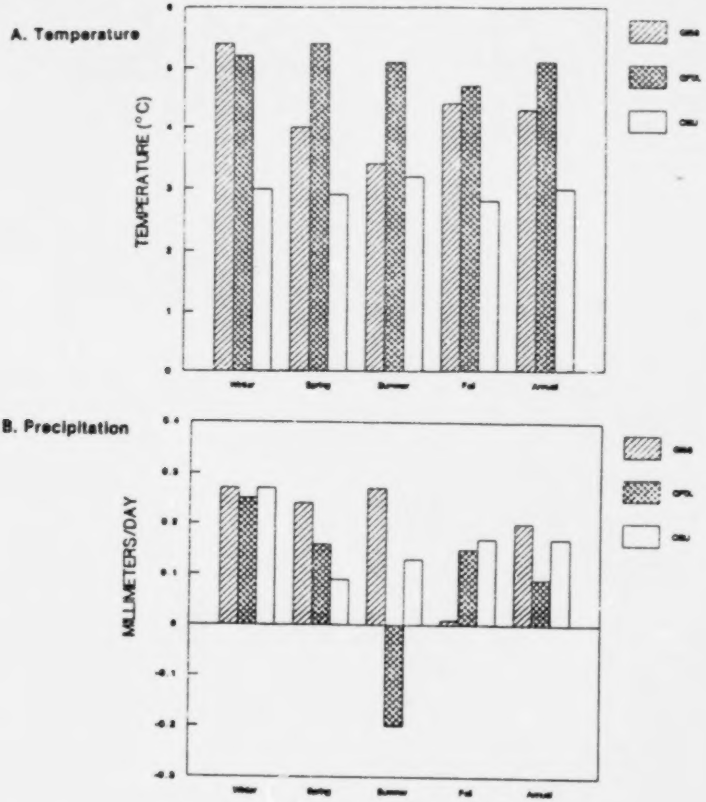


Figure 3. Average changes in temperature (°C) and precipitation (mm/day) over lower 48 States grid boxes from three GCM's (GISS = Goddard Institute for Space Studies, GFDL = Princeton Geophysical Fluid Dynamics Laboratory, OSU = Oregon State University).

Table 2. Summary of GCM Predictions[1]

Large Stratospheric Cooling. Reduced ozone concentrations in the upper stratosphere will lead to reduced absorption of solar ultraviolet radiation and therefore less heating. Increases in the stratospheric concentration of carbon dioxide and other relatively active trace gases will increase the radiation of heat from the stratosphere. The combination of decreased heating and increased cooling will lead to a major lowering of temperatures in the upper stratosphere.

Global-Mean Surface Warming. For an equivalent doubling of atmospheric carbon dioxide, the long-term global-mean surface warming is expected to be in the range of 1.5 to 4.5°C.

Global-Mean Precipitation Increase. Increased heating of the surface will lead to increased evaporation and, therefore, to greater global mean precipitation. Some individual regions might well experience decreases in rainfall.

Reduction of Sea Ice. As the climate warms, total sea ice is expected to be reduced.

Polar Winter Surface Warming. As the sea ice boundary is shifted poleward, enhanced surface warming in winter polar regions is likely. Warming of the polar surface air may be as much as 3 times the global mean warming.

Summer Continental Dryness/Warming. Several studies have predicted a marked long-term drying of the soil moisture over some mid-latitude interior continental regions during summer. this dryness is mainly caused by an earlier termination of snowmelt and rainy periods, and an earlier onset of the spring-to-summer reduction of soil wetness.

High-Latitude Precipitation Increase. As the climate warms, the increased poleward penetration of warm, moist air should increase the average annual precipitation in high latitudes.

Rise in global Mean Sea Level. A rise in mean sea level is generally expected due to thermal expansion of sea water in the warmer future climate. Far less certain is the contribution due to melting or calving of land ice.

---

[1] Modified from NAS (1987). (The original text should be consulted to understand the context completely.)

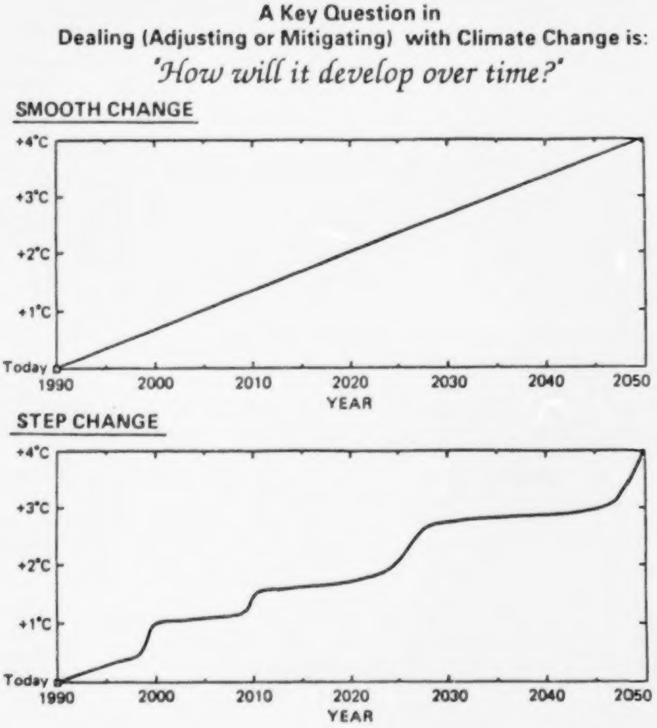


Figure 4. Possible ways that climate may change over the next 60 years.

Table 3. Major Climate Feedback Processes.

Water Vapor -- increased IR absorption

Ice and Snow Cover -- increased solar energy absorption

Cloud cover -- Changes in atmospheric transmission/reflectivity

Ocean Circulations -- changes in surface temperature distribution

Other Biosphere Processes -- changes in ecosystem

Table 4. Contributions by Trace Gas.

Carbon Dioxide	49%
Methane	18%
Chlorofluorocarbons	14%
Nitrogen Oxides	6%
Other	13%

Table 5. Contributions by Economic Sector.

Energy	57%
Chlorofluorocarbon Production	17%
Agriculture	14%
Forestry	9%
Other	3%

Table 6. Regional Contributions of Greenhouse Gas Emissions.

United States	21%
Soviet Union	14%
European Economic Community	14%
China	7%
Brazil	4%
India	4%
Rest of the World	36%

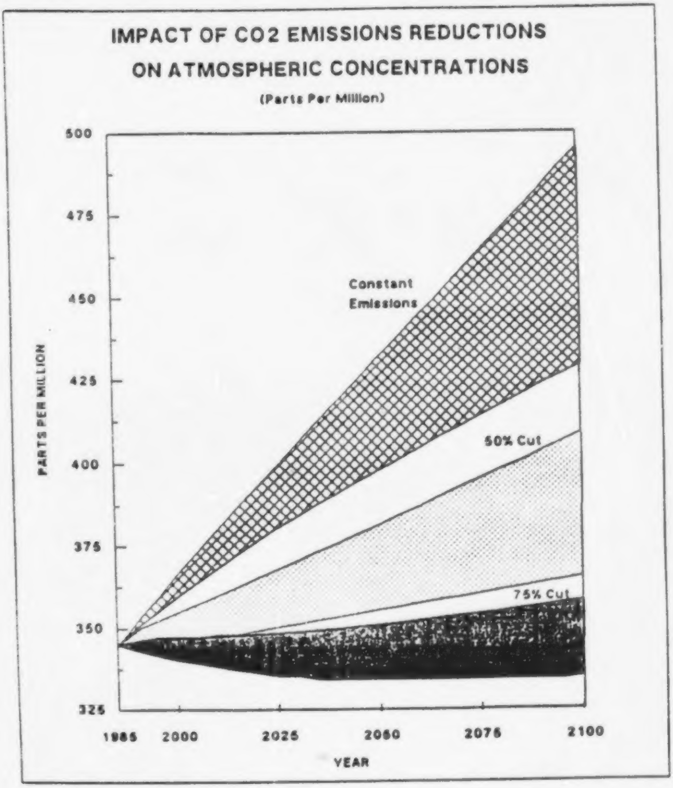


Figure 5. The response of atmospheric CO_2 concentrations to arbitrary emissions scenarios based on two one-dimensional models of ocean CO_2 uptake. (Sources: Hansen et al., 1984; Lashof, 1988; Siegenthaler, 1983).

THE SCIENCE AND POLITICS OF THE GREENHOUSE EFFECT: COLLISION COURSE?

Patrick J. Michaels
Department of Environmental Sciences
University of Virginia

It is doubtless that large-scale environmental changes known popularly as the "Greenhouse Effect" or "Global Warming" have commanded as much public attention as any environmental issue in recent history. As an example, *TIME* painted the following picture in its 1988 "Man of the Year" issue, featuring Planet Earth.[1] If left unchecked, anthropogenerated alterations of the atmosphere will bring, by the years 2030-2050, a global temperature rise of 4°C, ecological chaos including famine, related civil strife, and tidal waves crashing through a Manhattan landscaped with palm trees. As a rhetorical vehicle, I will refer to this scenario as the "Popular Vision" through this article.

Such scenarios also abound in the writings of politically active environmental scientists, environmental lobbyists, and newswriters.[2-5] United States elected officials have compared the current situation of that of Fascist Germany, where several events, such as Kristallnacht, presaged the holocaust. Those that do not recognize this have been labeled modern-day Neville Chamberlains[6]. Draconian interventionist legislation has been proposed[7] and the implementation of "global warming" is now a touchstone of U.S. foreign policy.[8]

Clearly, deep emotional commitments now guide this issue. In such a highly charged light, it would behoove us to examine the current state of the issue of anthropogenerated global warming.[9]

The balance of this essay will concentrate on some of the scientific uncertainties and inconsistencies that should be factored into policy decisions. Specifically, I will address the problems of (1) global and hemispheric temperature histories vis a vis trace gas concentrations, (2) "popular vision" climate models and their successors, (3) artificial warming from urban heat islands, (4) high latitude and diurnal temperatures, and (5) the holistic nature of the global change problem and negative feedbacks in the pollution system.

This compact review is a "reappraisal" of the Popular Vision as opposed to a "revisionist" view. The latter, in the sense of the social sciences, occurs primarily in the context of societal change, rather than in the light of new information. This "reappraisal" is tendered in the light of more refined scientific findings.

TRACE GAS CONCENTRATIONS AND TEMPERATURE HISTORIES

While there are several thermally active trace gasses that have increased as a result of anthropogeneration, almost all of the radiative forcing is associated with (in descending order) Carbon Dioxide, Methane, Nitrogen Oxides, and the Chlorofluorocarbons. The total radiative forcing of the last three is approximately equal to 80% of the effect of a change in CO_2 from 279 to 350 ppm.[10,11]

Intensive instrumental records of CO_2 concentration date from the late 1950's at Mauna Loa Observatory, where the 1958 annual average was 315 ppm. The concentration is now very close to 352 ppm.

"Pre-industrial" (circa 1800) concentrations were initially assumed to be in the range of 295 ppm,[12] giving a net increase of 19% over the last 190 years. Initial ice-core studies gave a background value of 270-290, with a most likely value of 279 ppm.[13] Another analysis obtained a lower bound of 260 ppm.[14] The highly publicized Soviet/French work on the long Vostok Station ice core appears to corroborate the lower values.[15,16] A background of 260 ppm implies an anthropogenerated rise of 35%. For a base year of 1800, Idso's comprehensive review uses a value of 281 ppm.[17]

Background CH_4 concentration, again calculated from ice cores, appears to be around 800 ppb,[18] compared to a current value of nearly 1700 ppb.[19] Indirect measurements give a concentration of 1140 in 1951.[20] The primary sources for this increase appear to be rice paddy agriculture and bovine flatulence. Neither of these seem likely to be reduced in the foreseeable future. An increasing fraction now comes from biomass burning.[21] Recent evidence suggests that both high intensity agriculture common over much of industrialized world, and "green revolution" culture in developing countries, reduces the rate at which methane is microbially resequestered from the atmosphere.[22]

It is clear that both CO_2 and CH_4 concentrations have risen exponentially in the last 40 years. As of 1982, the climate forcing effect of the methane concentrations was 38% of that of increased carbon dioxide.[23] A figure of 40% certainly seems reasonable for 1990.

Precise knowledge of the sources and sinks of the Nitrogen Oxides is unavailable, and background concentration estimates are must less reliable than those for the other trace gases. The historical estimate of 285 ppb should be taken with some caution, as should future projections. The current value is 298-308 ppb.[19]

Virtually all Chloro fluoro carbons (CFC's) are anthropogenerated. Concentrations from 1950 are estimated at .001 ppb for CFC-11, and .005 for CFC-12. Current values are .219 ppb for CFC-11 and .378 for CFC-12.[24] While the contribution of CFC's to the overall anthropogenerated radiative forcing is relatively small, they are highly efficient absorbers in the infrared; Lovelock[25] estimates that, on a molecule-for-molecule basis, the net warming effect of CFC's is 14 times greater than that of CO_2.

The 1987 estimate that the combined current radiative effect of the non-CO_2 trace gases is 80% of that caused by a change in CO_2 110 concentration from 279 to 350 ppm implies the current atmosphere can be viewed as having an effective CO_2 concentration of 411 ppm (assuming no other increases in thermally active gases), or 147-158% of a background range of 260-279 ppm. In other words, because of the combined effects of the various trace gases, we have already gone half way to an effective doubling of the preindustrial CO_2 concentration.

This will not be reversed in our lifetimes.

GLOBAL VERSUS HEMISPHERIC TEMPERATURE HISTORIES

It is customary to present the time history of global mean temperatures as "at least not contradictory to"[26] climate model projections. Calculations based upon the assumed radiative forcing in the penultimate suite of General Circulation Climate Models[27-31] (those that have given credence to the Popular Vision), produce an expected warming, after thermal equilibrium is established between the land, air and water, of 1.7 to date. The observed mean warming has been 0.4 - 0.6 since dense records began in 1860; these values are themselves subject to some reduction because of the urban warming detailed below. If a 260 ppm background is used instead, an analogous calculation gives an expected mean global warming of 2.0 to date. Inspection of the hemispheric temperature histories shown in Figure 1 reveals that much of the warming in the Southern Hemisphere, and virtually all the warming of the Northern Hemisphere was prior to the major increases in the trace gases.[32]

These discrepancies from the penultimate ("popular vision") suite of GCM's are well known, although their magnitude is seldom emphasized in public discussion or in the scientific literature; notable exceptions to this include Testimony to the U.S. Congress and the writings of Idso.[17,33]

The discrepancies are only partially explained as a function of oceanic thermal lag, whose e-folding time is estimated at from 10 to 70 years.

Nonetheless, even liberal estimates of this lag still imply an expected warming to date of 1.0 - 1.2°C,[10] suggesting that the globe has warmed up between a factor of two and three times (0.4 - 0.6) less than combinations of the penultimate generation of climate models coupled to rough approximations of oceanic lag. Why this much warming is "missing is simply unknown,[33] although we will speculate on causes here.

Intrahemispheric comparisons support the contention that oceanic thermal lag itself may be overestimated. The southern hemisphere, with the disproportionate share of ocean surface, displays a warming whose functional form (but not magnitude) is what might be expected from a straightforward interpretation of model output. The northern hemisphere shows most of its warming prior to the major input of trace gases, and shows no net change over the last 55 years[32] – when CO_2 concentrations went from approximately 300 to 352 ppm and the other thermally active gases were in their steepest growth phases, giving rise to the current effective concentration of 411 ppm.

Stratospheric temperatures, which should fall in a trace-gas enriched atmosphere, have dropped considerably more in the southern hemisphere than they have elsewhere, with the greatest declines in the polar zone. These may be associated with the south polar springtime ozone minimum.[17] There is no statistically significant trend in Northern Hemisphere stratospheric temperatures.[34]

"POPULAR VISION" AND NEW GENERATION CLIMATE MODELS

The penultimate generation of general circulation (GCM) climate models[27-31] calculated a mean equilibrium warming for a doubling of atmospheric CO_2 of 4.2, with maximum warmings (on the order of 15°) during North polar winter, and less significant warming (approximately two degrees) over tropical oceans. Figures 2 and 3 detail "typical" output from this suite of models.

These simulations prompted considerable attention from politicians, environmentalists and the press, as the projected climatic changes were doubtless of sufficient magnitude to result in major ecological disruption and significant rises in sea level. Further, even though many agriculturally important midlatitude areas were projected to see increases in precipitation, concomitant temperature changes resulted in evaporation rates that more than compensated for the rainfall, leading to projections of increased drought frequency. One modeller made a public "forecast" of increased drought frequency in the early 1990s.[35,36]

Figure 2 is included to demonstrate that, after some initial start-up, the temperature response of GCM's can be quite linear with respect to CO_2 or combined trace gas forcing, which has also been noted by Schneider.[37] The implication is that, if the atmosphere and ocean were approaching some equilibrium, enhanced warming should now be observed in polar regions, and midlatitude regions should be nearly two degrees warmer than background temperatures; obviously, neither of these events have occurred.

Major shortcomings in this generation of models included unrealistic ocean dynamics and ocean-atmosphere coupling, inadequate cloud parmeterization (which included debate on the sign and the magnitude of surface temperature forcing by clouds), and with one exception[28] the use of stepwise (instantaneous) doubling of CO_2 rather than the low-order exponential increase that exists in the real world.

Ramanathan et al.[38] demonstrated, using satellite observations, that the net effect of terrestrial cloudiness is a cooling of the surface. Since then, a more realistic cloud parameterization was introduced into the United Kingdom Meteorological Office (UKMO) model, and projected mean global warming dropped in that model from 5.5° to 2.7°.[39]

Two of the other four Popular Vision GCM's have recently included a more realistic coupling between the atmosphere and the ocean. The Geophysical Fluid Dynamics Laboratory model now projects a mean global warming (for a doubling of CO_2) of 1.8°, compared to 4.3° previously.[35] A similar recalculation in the National Center for Atmospheric Research (NCAR) model now predicts a warming of 1.6° instead of 3.7° in its earlier run.[40] Comparison of Figure 4 and Figure 3 shows how substantially the projected warming has been reduced.

All of these revisions occurred for models using an instantaneous doubling of CO_2, and it is tempting to view their unanimity of major reductions in projected warming as a sign of reliability. However, a transient version of the NCAR model, using an increase in radiative forcing that is quite close to what has actually occurred since 1950, suggests that current temperatures should be very nearly one degree above their 1950 value; global temperatures have in fact risen only 0.22° in that time, with the majority of the warming in the southern hemisphere. Thus, even conservative, transient models appear to be grossly overestimating prospective warming.

An additional problem is that this version, which is certainly as sophisticated as any, clearly predicts unrealistic regional temperatures for the current increase in trace gases. Figure 5 details the geographic distribution of December-February temperature changes expected in the year 26-30 average in a thirty year transient run in which trace gas forcing was increased in a realistic manner. Roughly speaking, the plot is analogous to any five year aggregate from 1975 through 1985. Neither the 2° - 4° warming of the northern half of North America, nor the 3° - 4° cooling of much of northern Eurasia, which comprises the major signal in the model, occurred in reality.

URBAN HEAT ISLANDS AND LONG-TERM SITE BIAS

Much has been written on the subject of urban contamination of long-term climate records, but its true magnitude remains elusive.

The most comprehensive recent studies are by Karl et. al.[41] that compared climate records of NASA and the East Anglia research group[32,42] – the two most cited records – to an unurbanized subsample over the United States. The NASA record makes no attempt directly to remove urban bias, while the East Anglia record does so subjectively. Karl et al. found an artificial warming in the NASA record of 0.4 in the twentieth century, and 0.10 - 0.15 in the East Anglia record; see Figure 6. There is no a priori reason to suspect that the urban bias is appreciably different in other parts of the industrialized world. Therefore, a simple extension to the globe – that is not possible to rigorously defend at this time because the exhaustive research has not been performed – would yield residual warming in the NASA record warming of 0.2° - 0.3°. The residual warming in the East Anglia record would be 0.25° - 0.40° during the 20th century.

While the considerable disparity between the NASA record and the analyses of Karl et al. remains unresolved, unpublished accounts now say it is related in part to a programming error when NASA supplied the data to NOAA for analysis.[43] Unpublished reanalyses place the bias in the 0.1° - 0.2° range. This is significant because it brings both the NASA and East Anglia curves into agreement that the net warming of this century is slightly less than a half of one degree. All records agree that much of this warming was prior to 1940, or before the major emissions of the thermally active trace gases. On the other hand, if the pre-1940 warming is ascribed to anthropogeneration, then the post-1940 global temperatures should have risen dramatically. They have not.

It should be noted parenthetically that statements about "99% confidence" of "cause and effect" between observed temperatures and anthropogenerated greenhouse alterations[44] did not take into consideration the very common and understandable human factors that may induce errors in the analysis. Figure 6 details the disparity between the NASA and Karl et al. records.

An additional, and more insidious, problem may be introduced into long-term climate records by a general site bias. Over what was the "developing world" of the late 19th century, the longest-standing records have tended to originate at points of commerce. Because of the predominance of water power during that era, it is likely that the longest records are from near-riverine environments. These sites are therefore located preferentially in zones where cold air drainage predominates. Such locations may be buffered from anthropogenerated climate changes, particularly in their nighttime temperatures.

In an attempt to compensate for riverine site bias, which doubtless occurs over peripolar regions such as Alaska, Michaels et al. calculated mean annual temperatures from the ideal gas law, based upon surface pressure and 500 mb heights, and purposefully neglecting thermometric measurements.[45] No net warming was detected since records began in 1948.

An analogous study calculated temperatures from 1000-50 mb thickness values over the U.S., southern Canada, and surrounding ocean regions.[46] While observations began in 1948, the record was extended back to 1885 by using an expanded version of Hayden's comprehensive cyclone track record.[47] The resulting temperature curve resembles the unurbanized mean annual U.S. temperature history of Karl et al.,[48] inasmuch as there is a rise from circa-1900 values to mid-century, followed by a fall through 1975, and a consequent rise through the 1980s. While the net temperature change is approximately +0.3°, the magnitude of the century-scale swing is twice that measured thermometrically (Figure 7). It is unknown whether this is related to the noise in the statistical transfer functions between the cyclone track record and the 1000-500 mb thickness, or whether it truly reflects free-atmosphere temperature variability. If the latter is true, then large, agriculturally important regions have experienced climatic changes in the 20th century that are not appreciably different from those projected by the improved GCM's.[35,39-40] GCM temperature calculations are based more upon free atmosphere conditions than they are on local site considerations, which they explicitly ignore. Thus, this temperature analysis is more directly comparable to model output than locally measured temperatures.

HIGH LATITUDE AND DIURNAL TEMPERATURES

Both the Popular Vision models and the new generation continue to predict amplified warming during winter in high latitudes, although the transient model of Washington and Meehl[40] has areas of both strong warming and cooling for a period roughly analogous to 1975-1985 (Figure 5).

As noted above, because of the combined effect of the thermally active trace gases, we have effectively gone beyond half way to a doubling of CO_2. It is quite apparent from Figure 8 that Arctic temperatures have simply not responded in the predicted fashion of the Popular Vision. In fact, the data indicate a rapid rise in temperature prior to the major emissions, followed by an equivalent decline.[49] The NCAR transient model run[40] is much more consistent with the observation of no net change in high latitude temperatures, although the strong cellular patterns indicated in that model have clearly not developed.

Observed antarctic surface temperatures show no trend whatsoever.[50] This is particularly noteworthy because some remote locations, such as Amundsen-Scott at the South Pole, have minimum problems that might compound the records such as marine advection, cloudiness, urban warming, or topographic effects that might induce local cold air drainage. In particular, the record during polar night is interesting: even though the effective change in trace gases has been considerable since the record began in 1957, there is no change whatsoever in the winter temperatures (Figure 9). How this could occur is surely mysterious, although it may indicate that the depth of the winter anticyclone is sufficient to buffer the station from any anthropogenic alternations of atmospheric composition. If this is the cause, then the problem of general site bias in long term records, noted above, is quite severe, as shallow cold air pooling may have the same effect worldwide.

Recent studies on diurnal temperatures do not bode well for the Popular Vision. Karl et al.[48] examined day and night temperatures using the U.S. Historical Climate Network (HCN), a record that contains a minimum of urban heating. Careful analyses indicate that daily temperature ranges have declined precipitously, concurrent with the major trace gas emissions. Interestingly, daytime high temperatures have actually declined, while night temperatures are rising relative to day values; see Figure 10. This behavior is consistent both with an increase in the trace gases and with increases in cloudiness that have been documented across the country.[51]

If anthropogenerated warming takes place primarily at night, the Popular Vision is simply wrong. Evaporation rate increases, which are the primary cause of projected increases in drought frequency, are minimized. The growing season is longer, because that period is primarily determined by night low temperatures. If cloudiness of any type continued to increase, the incidence of skin cancer would decline (after adjusting for age and behavior). Many plants, including several agriculturally important species, will show enhanced growth uninhibited by drought, because from the well-known "fertilizer" effect of CO_2.

Also, if warming is primarily at night, the component of sea level rise resulting from large-scale melting is drastically diminished, as virtually all polar melting takes place during polar day. At night, temperatures are so far below freezing that anthropogenerated warming is insufficient to induce melting.

Such a "positive" vision of the future climate has been promulgated by Soviet Academician Mikhail Budyko,[52] whose position in their national science hierarchy is analogous to those of, say, Steven Schneider or James Hansen in the United States. Clearly there is a very broad range of future climate expectations, and some of which are diametrically opposed to the Popular Vision.

THE HOLISTIC NATURE OF GLOBAL CHANGE AND NEGATIVE FEEDBACKS IN THE POLLUTION SYSTEM

One of the arguments often tendered concerning the certainty that disastrous warming either has begun or looms in the immediate future is based upon the co-occurrence of climate changes and CO_2 in antarctic ice cores dating back through the last glacial cycle. In fact, the resolution of those data is insufficient to determine whether or not changes in CO_2 presage or follow the climate change. However, even if they "cause" the change, the usefulness of the pleistocene analogy is severely limited by the cause of the current trace gas excursion: man.

It is clear that human activity, besides altering the concentration of thermally-active trace gases, also produces substances that can serve to counter that effect. These include particulates, which serve to scatter radiation, and sulfur dioxide molecules, which in their oxidized state can serve as cloud condensation nuclei. Anthropogenerated pollutants can therefore serve to "brighten" clouds, reflecting away increasing amounts of solar radiation, and possibly compensating for greenhouse warming. A recent calculation demonstrates that the magnitude of this effect could indeed explain the fact that the Northern Hemisphere, where most sulfate emissions occur, shows no net warming during the last half-century.[53]

Analyses of a limited set of satellite data confirm that ocean-surface stratocumulus – one of the most common clouds on earth, and the variety most likely to be affected by increasing numbers of condensation nuclei – indeed are considerably brighter in the lee of regions of major anthropogenerated sulfur dioxide emissions.[54] The brightening persists for thousands of miles downstream from the continental source regions. A control study, over the clean South Pacific, yields no strong trend in cloud brightness. Some of these results are shown in Figure 11.

Thus we are faced with the possibility that the same emission that causes acid rain may in fact be protecting the Northern Hemisphere from the disastrous greenhouse warming:

> "The effects of SO_2 associated with acidic precipitation and urban pollution are clearly detrimental, and measures to reduce emissions are being implemented widely. However, if we were successful in halting or reversing the increase in SO_2 emissions we could, as a by-product, accelerate the rate of greenhouse-gas-induced warming, so reducing one problem at the expense of another."[53]

While it is plausible that we have in fact compensated for trace-gas warming with sulfur oxides, it is unclear if or when increased trace gas loading will overcome this effect.

If human activity is indeed brightening clouds for thousands of miles in the lee of industrialized continents, energy balance considerations would suggest some localized net cooling in these midlatitude oceanic regions. It seems likely there would be some compensation for altered surface warming in the position of the jet stream. In particular, one would hypothesize that there would be a tendency for more frequent troughiness in the regions of relative cooling, such a downstream from Eurasia and North America, with a compensating tendency for ridge development in the eastern North Pacific ocean.

One consequence of this would be an increase in the magnitude of northwesterly flow over eastern North America, which has in fact been documented.[55,56] This could explain the cooling of the United States daytime temperatures from the mid 1930s to the mid 1980s,[48] or the dramatic drop (3°C) in southeastern mean winter temperatures over the last 60 years,[57] in the face of the trace gas increase.

THE CRISIS ON THE HORIZON

The intense politicization of the global change problem almost guarantees that some type of action will in fact be taken, as in the recent proposals by the President of the United States to drastically limit sulfur dioxide emissions. Nonetheless, the interrelatedness of the components of global change dictates that any single remedial activity – such as a reduction in sulfate emissions in an attempt to reduce acid rain – can have unforseen or negative consequences that could in fact serve to exacerbate the much more serious problem of potential anthropogenerated warming.

A crisis will soon occur in environmental politics when the public realizes that, regardless of the remedial attempts that are invoked, concentrations of most greenhouse gases will continue to increase. In particular, reduction of methane or CO_2 to the point that atmospheric concentrations stabilize seems unlikely for several decades. Responses to large-scale environmental disturbances that do not take into consideration the interrelatedness between environmental problems can make the specter of climatic change much more imminent.

If global warming continues to be expressed primarily in night temperatures (if indeed that is what is occurring now), will a public that has endured an intense campaign suitable enough to ensconse the Popular Vision suddenly accept climate change as possibly benign? What will become of the credibility of the scientists and politicians who have in all earnestness and out of genuine concern promoted that Popular Vision?

Alternatively, if the Popular Vision indeed begins to verify – which may require a reversal of trends that have developed since the major increases in trace gases – the public will have to choose a mix of two actions: direct and purposeful intervention in the climate system (as proposed by Budyko) and/or attempts at adaptation. According to Academician Budyko:

> "Another approach to limiting global warming . . . (is) accessible even to modern technology (and) was proposed long before the onset of wide international studies on anthropogenic climate changes. The main idea of this method is to increase the stratospheric aerosol concentration by burning sulfur delivered by aircraft into the lower stratosphere.
>
> It can be noted that this method will require incomparably (emphasis ours) less expense than those due to damage caused by drastic reductions in carbon fuel consumption aimed at retarding global warming. One other most important advantage

> of this method is the possibility to considerably change climate to cooling for a short period of time . . ."[58]

It seems highly improbable that a public that is abnormally risk-averse, as evinced by the recent ALAR controversy in the United States, will agree to this remedy.

CONCLUSION

The Popular Vision of the world influenced by increasing concentrations of trace gases is one of ecological disaster brought on by rising temperatures, sea level, and evaporation rates. This Vision, which developed from the penultimate suite of climatic models, persists, even though the newer, more physically realistic models have all lowered their estimates of warming by more than a factor of two. The Vision continues to be espoused despite several other lines of observational evidence that indicate such a "carbon dioxide indisasterous warming out" concept is immature at this time. Given the complexity of the global change problem. Nonetheless, politicians have compared the severity of the expected paroxsysms to those of the Nazi holocaust. Global warming is now one touchstone of U.S. foreign policy.

This evolved in the light of remarkable inconsistencies. The northern hemisphere, which should be the first to warm, is no warmer than it was 55 years ago. One very careful study shows relative warming at night, which may in fact be beneficial. The amount of measured global warming is at least a factor of three less than predicted by our most sophisticated models. High latitude temperatures, which some calculations indicated should be most sensitive, show no "greenhouse" signal. If findings about urban contamination of climate records over the U.S. persist worldwide, the amount of warming over the last 120 years is even less than the generally accepted 0.5°. Finally, there is evidence that other anthropogenerated compounds may in fact be mitigating the expected warming.

Nonetheless, we have now embarked on a road to eliminate some compensating emissions, even while there is universal agreement that the concentrations of greenhouse gases will continue to increase, despite our best efforts.

A crisis in environmental politics lurks on the horizon. If the greenhouse expression is most likely to be primarily benign, it will be very difficult to convince a public that is now so highly sensitized to accept it. If in fact the Popular Vision appears likely – something that is becoming more remote as climate simulations become more realistic – it will be equally difficult to convince the public that some type of direct intervention and adaptation may be the only viable remedy.

NOTES

1. *Time* Magazine's 1988 "Man of the Year" issue was changed to "Planet of the Year" to underscore their perception of the importance of this current crisis.

2. As an example of a politically active environmental scientist espousing this view, see Titus, J.G., "Rising Sea Levels: The Impact they Pose," EPA Journal. 1986.

3. Lobbyist example: Speth, G., "Can the Human Race be Saved?", EPA Journal, 1989, 47-50.

4. Philip Shabecoff of the New York Times provides many examples; one of the best appeared in the Sacramento (California) Bee on July 3, 1988 as a sidebar titled "Now for a worst-case scenario."

5. An excellent compilation of these reports can be found in "The Atmospheric Crisis: The Greenhouse Effect and Ozone Depletion," Social Issues Resource Series, POB 2348, Boca Raton, FL 33427.

6. Gore, A.V., Jr., 1989. "An Ecological Kristallnacht. Listen," New York Times, March 18, 1989.

7. See Senate Bill 603, sponsored by R.M. Boschwitz and A.V. Gore, Jr.

8. Goshko, S.M., The Washington Post, January 31, 1989.

9. It is important to distinguish Anthropogenerated Global Warming from Atomic or "Natural" Global Warming that appears to accompany the exit from the "little ice age" that ended in the 19th century.

10. Wigley, T.M.L., 1987. Relative Contributions of Different Trace Gases to the Greenhouse Effect. Climate Monitor 16, 14-28.

11. Warrick, R.A. and P.D. Jones, 1988. The Greenhouse Effect: Impacts and Policies. Forum for Applied Research and Public Policy, 3, 48-62.

12. Schlesinger, M.E., 1982. The Climate Change Induced by Increasing Atmospheric Carbon Dioxide. In Carbon Dioxide Proliferation: Will the Icecaps Melt?, Special Publication #21 of the IEEE Power Engineering Society, pp. 9-18.

13. Neftel, A., E. Moor, H. Oeschger, and B. Stauffer, 1985. Evidence from Polar Ice Cores for the Increase in Atmospheric CO_2 in the past two centuries. Nature 315, 45-47.

14. Raynaud, D., and J.M. Barnola, 1985. An Antarctic Ice Core Reveals Atmospheric CO_2 Variations over the Past Few Centuries. Nature 315, 309-311.

15. Lorius, C., J. Jouzel, C. Ritz, L. Merlivat, N.I. Markov, Y.S. Korotkevich, and V.M. Kotlyakov, 1987. A 160,000 year Climatic record from Antarctic Ice. Nature, 239, 591-596.

16. Jouzel, J., C. Lorius, J.R. Petit, C. Genthon, N.I. Barkov, V.M. Kotlyakov, and V.M. Petrov, 1987. Vostok Ice Core: A Continuous Isotope Temperature Record over the Last Climatic Cycle (160,000 years). Nature, 239, 403-408.

17. Idso, S.B., 1989. Carbon Dioxide and Global Change: Earth in Transition. IBR Press, Tempe, AZ 85282. 292 pp.

18. Pearman, G.I., D. Etheridge, F. deSilva, and P.D. Fraser, 1986. Evidence of Changing Concentrations of Atmospheric CO_2, N2O and CH_4 from Air Bubbles in Antarctic Ice. Nature 320, 248-250.

19. Rasmussen, R.A., and M.A.K. Kahlil, 1986. Atmospheric Trace Gases: Trends and Distributions over the Last Decade. Science 232, 1623-1624.

20. Rinsland, C.P., J.S. Levine, and T. Miles, 1985. Concentration of Methane in the Troposphere Deduced from 1951 Infrared Solar Spectra. Nature 318, 245-249.

21. Craig, H., C.C. Chou, J.A. Whelan, C.M. Stevens, and A. Engelmeier., 1988. The Isotopic Composition of Methane in Polar Ice Cores. Science 242, 1535-1539.

22. Stueudler, P.A., R.D. Bowden, J.M. Melillo, and J. Aber, 1989. Influence of Nitrogen Fertilization on Methane Uptake in Temperate Forest Soils. Nature, 341, 314-316.

23. Craig, H., and C.C. Chou, 1982. Methane: The Record in Polar Ice Cores. Geophys. Res. Let. 9, 1221-1224.

24. Hansen, J.E., A. Lacis, D. Rind, G. Russell, P. Stone, I. Fung, R. Ruedy, and J. Lerner, 1984. Climate Sensitivity: Analysis of Feedback Mechanisms. Geophys. Mono Ser. 29, 130-163.

25. Lovelock, J., 1988. The Ages of Gaia: A Biography of Life on Earth. Norton, New York, 252 pp.

26. MacCracken, M.C., and G.J. Kukla, 1985. Detecting the Climatic Effects of Carbon Dioxide: Volume Summary. In Detecting the

Climatic Effects of Increasing Carbon Dioxide, United States Department of Energy, Publication DOE/ER-0235, 163-176.

27. Manabe, S., and R.T. Wetherald, 1980. On the Distribution of Climatic Change Resulting from an Increase in the CO$_2$ Content of the Atmosphere. J. Atmos. Sci. 377, 99-118.

28. Hansen, J., I. Fung, A. Lacis, D. Rind, S. Lebedeff, F. Ruedy, and G. Russell, 1988. Global Climate Changes as Forecast by the Goddard Institute for Space Studies 3-Dimensional Climate Model. J. Geophys. Res., 93, 9341-9364.

29. Schlesinger, M.E., 1984. Climate Model Simulation of CO$_2$-Induced Climatic Change. Advances in Geophysics, 26, 141-235.

30. Mitchell, J.F.B., 1983. The Seasonal Response of a General Circulation Model to Changes in CO$_2$ and Sea Temperature. Quart. Jour. Royal Meteor. Soc., 198, 113-152.

31. Washington, W.M., and G.A. Meehl, 1983. General Circulation Model Experiments on the Climatic Effects Due to a Doubling and a Quadrupling of Carbon Dioxide Concentration. J. Geophys. Res., 88, 6600-6610.

32. Graphics supplied by H.F. Diaz, U. of Massachusetts of data of P.D. Jones and T.M.L. Wigley, University of East Anglia.

33. Testimony of Patrick J. Michaels to the Committee on Foreign Relations, United States Senate, April 20, 1989.

34. Angell, J.K., 1986. Annual and Seasonal Global Temperature Changes in the Troposphere and Low Stratosphere. Mon. Wea. Rev., 107, 1922-1930.

35. Kerr, R.A., 1989. Hansen vs. the World on the Greenhouse Threat. Science, 244, 1041-1043.

36. This forecast forms a testable hypothesis. If one takes the definition of the "early 1990's" strictly, this comprises the period January 1, 1990 through December 31, 1993. Where available, Palmer Drought values should be calculated during this period and compared to a long-term mean. The comparison should not be made over mountainous areas, as the Palmer Index is insensitive to snowpack and snowpack irrigation.

37. Schneider, S.H., 1989. The Greenhouse Effect: Science and Policy. Science 243, 771-781.

38. Ramanathan, V., R.D. Cess, E.F. Harrison, P. Minnis, B.R. Barkstrom, E. Ahmad, and D. Hartman, 1989. Cloud-Radiative Forcing and

Climate: Results from the Earth Radiation Budget Experiment, Science, 243, 57-63.

39. Mitchell, J.F.B., C.A. Senior, and W.J. Ingrahm, "CO_2 and Climate: A Missing Feedback?" *Nature*, Vol. 341 (1989), 132-134.

40. Washington, W.M., and G.A. Meehl, "Climate Sensitivity due to increased CO_2: Experiments with a Coupled Atmosphere and Ocean General Circulation Model." *Climate Dynamics*, Vol. 4 (1989), 1-38.

41. Karl, T.R. and P.D. Jones, 1989. Urban Bias in Area-Averaged Surface Air Temperature Trends. Bull. Amer. Met. Soc., 70, 265-270.

42. Hansen, J., and S.L. Ebedeff, 1988. Global Surface Air Temperatures: Update through 1987. Geophys. Res. Let., 15, 323-326.

43. T. Karl, Personal Communication to P.J. Michaels, 5/89.

44. Testimony of J.E. Hansen to U.S. House of Representatives, 6/88.

45. Michaels, P.J., D.E. Sappington, and D.E. Stooksbury, 1988. Anthropogenic Warming in North Alaska? J. Climate 1, 942-945.

46. Michaels, P.J., D.E. Sappington, and D.E. Stooksbury, 1989. Regional 500 mb Heights Prior to the Radiosonde Era. Proceedings, 6th Conference on Applied Climatology, American Meteorological Society, Charleston, S.C., 184-187.

47. Hayden, B.P., 1981. Secular Variation in Atlantic Coast Extratropical Cyclones. Mon. Wea. Rev., 198, 159.-167.

48. Karl, T.R., R.G. Baldwin, and M.G. Burgin, 1988. Time Series of Regional Season Averages of Maximum, Minimum, and Average Temperature, and Diurnal Temperature Range across the Untied States, 1901-1984. U.S. Dept. of Commerce, Historical Climatology Series 4-5, National Climatic Data Center, Asheville, N.C. 108 pp.

49. Elsaesser, H.W., M.C. MacCracken, J.J. Walton, and S.L. Grotch, 1986. Global Climatic Trends as Revealed by the Recorded Data. Rev. Geophys. 24, 745-792.

50. Sansom, J., 1989. Antarctic Surface Temperature Time Series. J. Climate 2, 1164-1172.

51. Seaver, W.L., and J.E. Lee, 1987. A Statistical Examination of Sky Cover Changes in the Contiguous United States. J. Clim. Appl. Meteor. 26, 88-95.

52. Budyko, M.I., 1988. Paper read to the first meeting of the Climate Trends Panel, held at National Research Council, September, 1988.

53. Wigley, T.M.L., 1989. Possible Climate Change Due to SO_2-Derived Cloud Condensation Nuclei. Nature 338, 365-367.

54. Cess, R.E., Presentation to U.S. Department of Energy meeting on research planning for Global Change, Germantown, MD, 4/89.

55. Michaels, P.J., P.J. Stenger, and D.E. Sappington, 1989. Atmospheric Pollutant Transport: Take It or Leave It. Proceedings, 6th Conference on Applied Climatology, American Meteorological Society, Charleston, S.C., 184-187.

56. Wallace, J.M., and D.S. Gutzler, 1981. Teleconnections in the Geopotential Height Field during Northern Hemisphere Winter. Mon. Wea. Rev., 109, 784-812.

57. Balling R.C., and S.B. Idso, 1989. Historical Temperature Trends in the United States and the Effect of Urban Population Growth. J. Geophys. Res., Vol. 84, 3359-3363.

58. Budyko, M.I., and Yu.S. Sudunov, 1988. Anthropogenic Climatic Changes. World Congress, Climate and Development, Hambur, FRG, 21 pp.

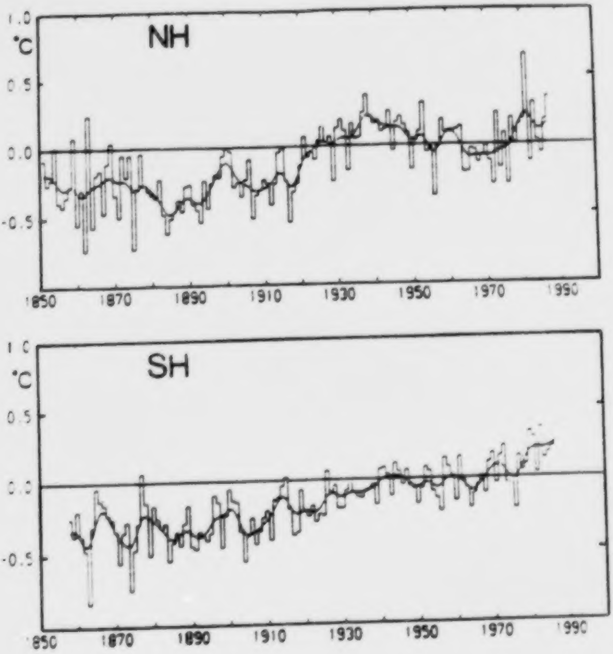


Figure 1. TOP: Southern Hemisphere temperature behavior for the last half century resembles what one would expect from a greenhouse alteration, except the magnitude of the rise apppears to be low. BOTTOM: Virtually all of the warming in the Northern Hemisphere record took place prior to the major trace gas emissions; there has been no net warming for the last half century[32].

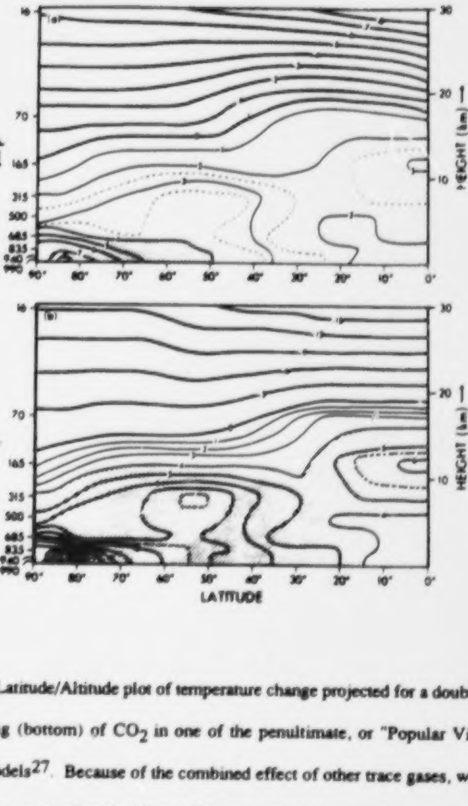


Figure 2. Latitude/Altitude plot of temperature change projected for a doubling (top) and a quadrupling (bottom) of CO_2 in one of the penultimate, or "Popular Vision" suite of climate models[27]. Because of the combined effect of other trace gases, we are now over half-way to an equivalent doubling of the background concentration.

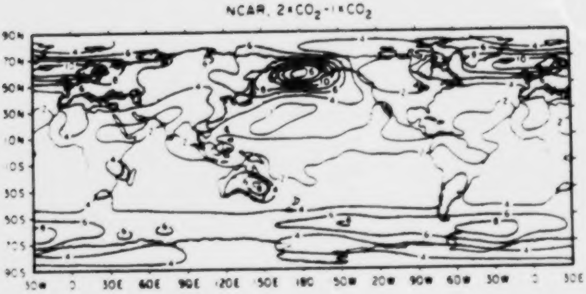


Figure 3. Winter (DJF) equilibrium temperature changes projected by another of the penultimate generation of models[31] (The National Center for Atmospheric Research Community Climate Model). Compare to Figure 4.

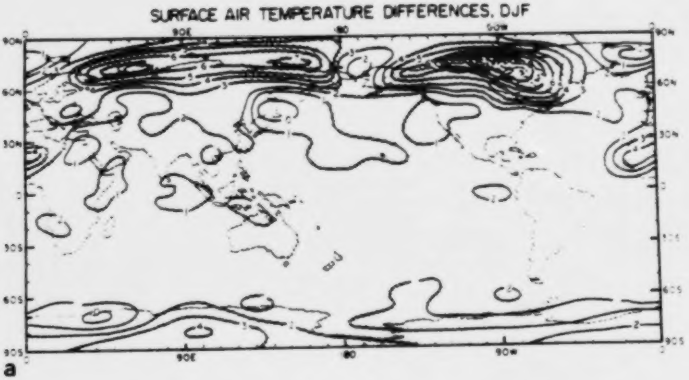


Figure 4. The new version of the NCAR-CCM using more realistic ocean and ocean-atmosphere dynamics. Compare to Figure 3.

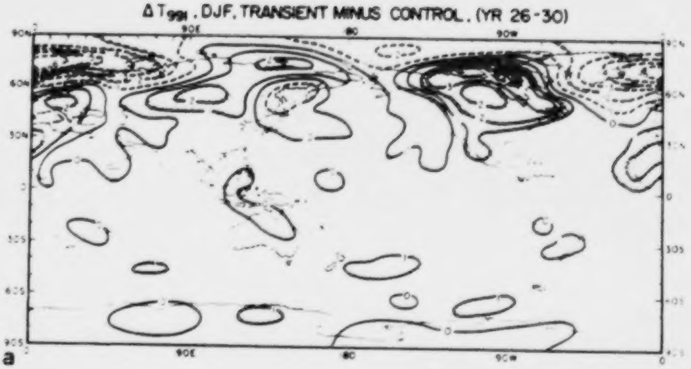


Figure 5. Calculated regional temperature changes from background in the year 26-30 average of a simulation that realistically simulates the trace gas forcing increase since 1950. Magnitude of both the projected warming (over northern North America) and the cooling (over northern Eurasia) have not been observed.

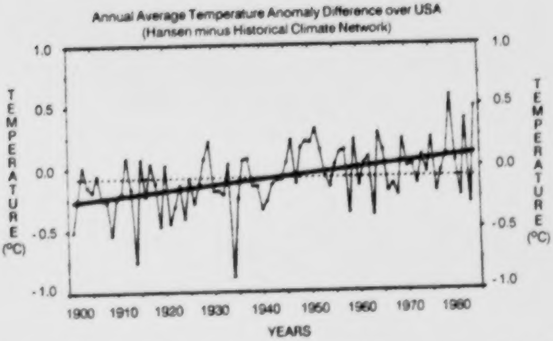


Figure 6. NASA's record over the coterminous U.S. warms up approximately 0.4° C compared to the urbanization-adjusted Historical Climate Record. The discrepancy may result from a programming error.

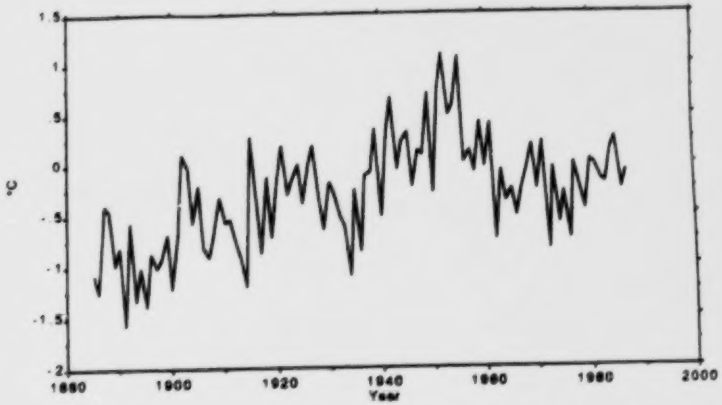


Figure 7. The temperature history of the U.S., Southern Canada, and surrounding oceans calculated from the 1000-500mb proxy record[46] shows climatic variation not appreciably different than that projected by the new family of GCM's[35, 39-40].

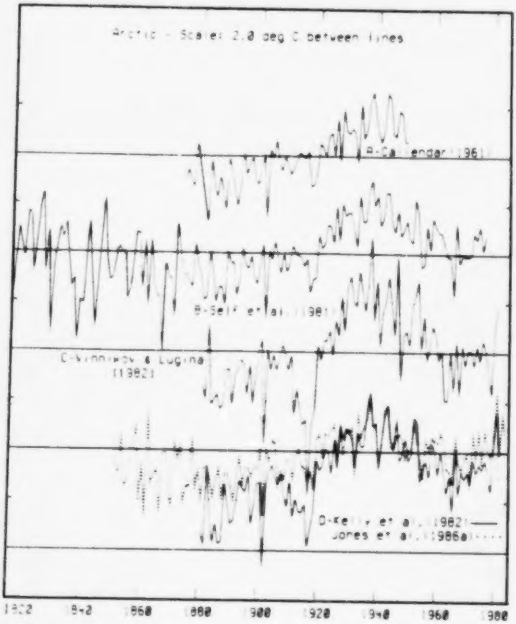


Figure 8. Arctic temperature records[49]

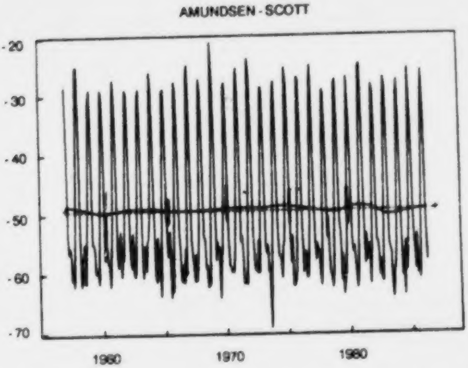


Figure 9. The record at Amundsen-Scott (South Pole), where compounding influences are likely to be absolutely minimized, shows no change in polar night temperatures in spite of the massive increase in infrared-absorbing trace gases[50].

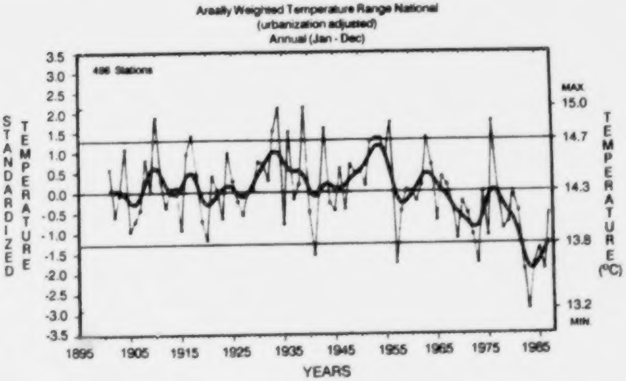


Figure 10. The difference between United States daily high and low temperatures. The narrowing of the range is consistent with a benign expression of the trace gas changes.

GREENHOUSE WARMING: SCIENCE VS. CONSENSUS

Richard S. Lindzen
Center for Meteorology and Physical Meteorology
Massachusetts Institute of Technology

The assessment of the proper response to the possible danger of global warming depends critically on the determination of how likely the danger really is. There are certainly other potential problems that could be far more devastating for life on this planet (an asteroid collision for example), but that we regard as too unlikely to worry about.

Judging from much of what one sees in the media, there is little doubt about the coming global warming. The question is simply whether it will be unprecendentedly bad (1.5° warming) or worse (5°C warming). To quote from Stephen Schneider at a recent conference hosted by Robert Redford at Sundance, Utah, 'there will be no winners.' The Democratic National Committee has made dealing with the warming an issue on a par with dealing with the drug problem.[1] Still, if one visits the Center for Meteorology and Physical Meteorology at M.I.T. (where I happen to teach) one encounters a general attitude of skepticism. There is a common feeling at M.I.T. and elsewhere, that this question has become enmeshed in hysteria. Such environmental scares are not unheard of. In recent years we have confronted the destruction of the ozone layer by supersonic transports, the coming ice age (popular in the early 70s, and the subject of Stephen Schneider's book, *The Genesis Strategy*), and nuclear winter. All these scares have withered for good reason. It is only fair to add that none of these earlier scares has been put forth with the vehemence associated with 'global warming.' In this paper, I propose to go over the scientific bases for our present concerns. I hope to show that both the data and our scientific understanding do not support the present level of concern. If time permits, I also would like to go over some aspects of the public treatment of this problem that bode ill for science itself.

Let me begin by putting forth some of the major contentions that are commonly treated as facts:

1. CO_2 has increased from 315 ppm to 350 ppm since 1958.

2. Preindustrial levels of CO_2 were on the order of 270 ppm.

3. CO_2 is likely to double over the next century or so.

4. An increase of global mean temperature of 1.5 - 5°C is expected to accompany a doubling of CO_2.

5. Over the last century, a warming of 0.5° ± 0.2° has occurred.

6. Greenhouse gases absorb infrared radiation; therefore, increasing the concentration of such gases must cause the earth to cool less effectively, and hence heat up.

The first item is based on measurements taken at Mauna Loa Observatory since 1958. The record of these measurements is shown in Figure 1 (at end of paper). The increase is unambiguous, and because CO_2 is relatively well mixed in the course of a year, the increase is likely to be representative. Thus, the first contention appears to be solid. It would be difficult to look at Figure 1 without concluding that concentrations were less in 1958 than in the 19th century, and that they will be greater than they are at present a hundred years from now. The quantitative evaluation of these changes is however, by no means trivial. The increase since 1958 corresponds to about half the CO_2 created by fossil fuel combustion alone. In addition there are additional sources associated with deforestation and 'slash and burn' agriculture. The bulk of the CO_2 introduced into the atmosphere seems to be taken up in the oceans that contain many times the CO_2 in the atmosphere. However, the nature of the mechanisms whereby the ocean is presumed to take up CO_2 are extremely unclear at present. This uncertainty as well as uncertainties concerning future and past production makes extrapolation of the results in Figure 1 difficult. Nevertheless, items 2 and 3 are at least plausible[2] It is entirely legitimate to ask whether we should be worried. Certainly, we are dealing with significant changes in CO_2 itself, but this alone need not be serious. CO_2 is a minor constituent (about 0.03% of the atmosphere), and as such its variations might not be too important. One can imagine some gas that is not normally present in the atmosphere. Releasing a molecule or two of such a gas would represent an enormous percentage increase without being of such concern. As it turns out, there are quite a few things that increasing CO_2 might do. For example, the atmosphere at altitudes between 25 km and 90 km is cooled primarily by thermal radiation emitted to space by CO_2. Increasing CO_2 should cool these regions, and this, in turn, should lead to increasing concentrations of ozone at these levels.[3] Increasing CO_2 also might stimulate the growth of vegetation. These possibilities are being studied, and are, on the whole, benign or even beneficial. As far as we know, there is no direct adverse effect on human beings arising from increases in CO_2 on the order of those anticipated (however uncertainly) over the next few centuries (certainly much higher concentrations are found in normal indoor environments). Our main concerns have focussed on the possibility that increasing CO_2 might significantly warm our climate. Although we do not know exactly what determines the concentrations of CO_2, it is eminently plausible to ask what a doubling of present concentrations of CO_2 would do. For reasons that I will discuss later, there is pretty general agreement that increasing CO_2 will reduce warming. Such a conclusion, by itself, is pretty useless. As has often been noted, science without numbers is not quite science. What we need to know is how much warming can be expected. If the expected warming is significantly less than the natural fluctuations in climate then there is little basis for useful concern. Item 4 suggests the expectation that very significant warming will indeed take place. These estimates arise from model calculations.[4] To be sure the models are notoriously inadequate (including those models running on large computers); this is a matter we will discuss in greater detail later in this talk. For the moment, we wish to note that such large predictions suggest that the changes in CO_2 that have occurred over the last 150 years should already have produced warmings of about 0.75° - 2°C. According to item 5, only the lowest of these estimates is even marginally consistent with past observations. This is a matter of some importance since this is the only observational evidence for anomalous greenhouse warmings available now. As we shall see, the data, although quite uncertain, do not suggest that even this degree of warming has, in fact, occurred.

The determination of the globally averaged temperature of the earth's surface is a difficult task – at least at the level of accuracy we require for the present purpose. As everyone knows from personal experience, temperature can vary markedly over short distances; urban areas are frequently warmer than the countryside; water surfaces differ in temperature from adjacent land surfaces; temperatures vary in the course of a day; seasonal changes are large. Moreover, there is what is referred to as 'natural' because it is expected to occur even in the absence of external causes.[5] It is not clear that our network of surface temperature measurements is adequate to eliminate these sources of uncertainty. However, such averages as we are able to form show remarkable constancy from year to year. Estimated changes over the last 150 years are less then 1°C.[6] We cannot be at all sure that these small changes are not in significant measure due to inadequate and/or improper sampling. For starters, most of the earth's surface is covered by oceans over which we have no fixed station records. The most commonly cited time series for globally averaged temperature is based solely on such fixed station records. Temperatures measured at St. Helena Island are assumed, for example, to be characteristic of almost a third of the Atlantic Ocean; this is unlikely to be a sufficiently good assumption for the purpose of determining the small changes in global temperature. There are, as it turns out, many records of temperature at seas taken from ships.[7] These data also present problems. Among other things, differences arise depending on whether water was sampled by bucket or through intake. For certain regions of the globe (namely the contiguous 48 states), there has been consistent and relatively dense measurement of temperature since the 1890's. Since this region is only a small portion of the earth's surface, it is a priori expected to be more variable than the globe as a whole. In addition there is a substantial difficulty in correcting this record for the effects of urbanization. The National Climatic Data Center of NOAA (National Oceanic and Atmospheric Administration) has approached this correction with considerable care, but, again, the issue remains a matter of some debate.[8] Since the above date is about all we have, it is what we will have to use. However, it is important to stress that all the above records have required uncertain corrections whose magnitude is as large as the climatic effects being sought. Under these circumstances, any scientist would intuitively regard any conclusions regarding such effects as suggestive at best. Only if the observed changes were substantially larger than the corrections would they be regarded as convincing. As we shall now see, this is not at all the case.

In Figure 2, we show three time series for annually averaged surface temperature. The top record is an area weighted average (that is to say records are weighted in proportion to the area they represent) of fixed surface measurements from all over the globe; it dates back to 1855. The middle record is derived from millions of ship records, and also dates from about 1855. The bottom curve is for the contiguous 48 states, and dates back to 1900.[9] All these records begin before the bulk of industrial CO_2 deposition into the atmosphere. Although all three series differ in detail, none indicate variability significantly in excess of 1°C. None indicate any significant temperature change between the start of the record and the present. Finally, the best record (that for the 48 contiguous states), and the record expected to show the greatest variability because of the small area covered, shows almost no significant trend at all. On the basis of the available records, our best estimate for the global temperature change that has occurred over the industrial period does not significantly vary from zero, and this certainly suggests that current models are greatly exaggerating expected warming. The contention in item 5 comes from considering the top curve in Figure 2 to begin around 1880.[10] There is, in fact, a good reason to begin with 1880. Before this date there was little attempt to systematically organize and collect global climate data. However, earlier – albeit sparcer – data does exist that suggests that earlier temperatures were warmer. Even beginning at the 1880 minimum, the record is hardly one of uniform increase. The major sharp increase occurred by 1940. This increase antedated the much greater increase in CO_2 deposition after this date, and might reasonably be interpreted as a return of the global temperature to its value before the anomalous minimum around 1880. From 1940 until the 1960's the record suggested global cooling (leading to the suggestions in the 1960's that an ice age was coming). Beginning in the 1960's there is evidence of a reversal of the earlier cooling trend (leading to the current suggestions of global warming). It should be emphasized that the record is merely suggestive. The absence of a trend in the record for the contiguous 48 states leads to the suspicion that all the trends in the global record may, in fact, be spurious. We certainly cannot assert that no warming occurred; however, the data does not show it.

The above difficulty with detecting trends was clearly recognized in NRC83. They suggested that this difficulty might be circumvented by a technique they referred to a 'fingerprinting.' The idea behind this approach was simply that models predict a detailed distribution of temperature and not simply a globally averaged temperature. Perhaps the data might confirm patterns of regional change more clearly than it could detect trends in globally averaged temperature. The trouble with this approach arises from the fact that existing models differ pronouncedly (sometimes even in sign) in their predictions of regional variations. The models do not even do a good job in simulating present day regional variations. About the only thing existing climate models agree on is the warming will be greatly exaggerated in polar regions – especially during winter. These predictions are shown in Figure 3. Unfortunately, observations show that exactly the opposite has occurred in the arctic; as we see in Figure 4, the arctic is not warming, but rather appears to be a cooling trend which is particularly pronounced in winter.[11]

Given the data alone, we would have little basis for alarm. The alarm arises instead from theoretical considerations – namely the so-called 'greenhouse effect.' The idea here is quite simple. Averaged over several years, the surface of the earth is in a state of approximate thermal balance. In particular, cooling balances heating. If the earth had no atmosphere at all, this balance would be achieved by radiation alone. The heating would be due to the absorption of sunlight, and the cooling would be due to the thermal (infrared) radiation which increases with increasing temperature. The temperature would rise (or sink) until heating and cooling balanced. It can be shown that such a balance would lead to an average surface temperature of about -18°C – a value much lower than what is actually found that is close to + 15°C. The difference arises because the earth does have an atmosphere, and that atmosphere contains infrared absorbers. These absorbers are known as greenhouse gases. What happens is that these absorbers absorb some of the infrared radiation cooling the earth and reemit the radiation both upward and downward. The downward component supplements the radiation from the sun. Thus the earth must warm up so that the total radiation incident on the earth can be balanced by cooling. This is known as the 'greenhouse effect.[12] The process is schematically illustrated in Figure 5. Far and away the most important infrared absorbers are water vapor and liquid water in the form of cloud droplets arrayed in stratiform, i.e., layer, clouds. (The latter also acts to reflect sunlight, which is a cooling effect; the heating and cooling effects almost balance. It is currently believed, however, that the cooling effect slightly exceeds the warming effect.[13]) Additional minor absorbers like CO_2, ozone, nitrous oxide, and methane contribute a little to this effect, and all other things being equal, we may expect increasing absorber amounts will lead to increased surface temperature. However, it should be pointed out that the contributions of the minor greenhouse gases to warming are small even compared to the estimated slight difference between the warming and cooling properties of stratiform clouds. The above picture is hardly new; it was reasonably understood by the early part of this century. It was also known that the above picture as applied to the earths surface was too simple.

The point is that the surface of the earth does not cool primarily by infrared radiation.

The surface of the earth cools mostly by evaporation.[14] (See Fig. 6) Most of the evaporated moisture ends in convective clouds (clouds with strong vertical currents that bodily carry the air and its contents upward, as opposed to layered clouds which form and stay at a particular level) where the moisture condenses into rain. Just as evaporation cools, the condensation of water vapor heats, and the atmosphere realizes most of this heat at altitudes greater than 5 km. It is at these heights that the atmosphere must balance the heat deposited by convection from the surface with cooling by thermal radiation. It is worth noting that in the absence of convection, pure greenhouse warming would lead to a globally averaged surface temperature of +72° for current conditions.[15] Our current average temperature, +15°C, is actually closer to the black body temperature (without any greenhouse warming), -18°, than to the pure greenhouse result. It follows that it is primarily the distribution of infrared absorbers above 5 km (rather than below 5 km) that is important for the earth's temperature.[16] On the face of it, this is only a minor gloss on the simple model of the purely radiative greenhouse. However, as we shall soon see, it has major implications for current predictions. In the mean time we see that item 6 is not nearly as straightforward as is commonly stated.

The physics described in the above few paragraphs is characteristic of all current models used to estimate the effect of doubling CO_2. These models include simple models that are readily evaluated on a small PC and gigantic codes that require supercomputers. Not surprisingly, results differ relatively little among these various models. Such differences as exist do not stem from differences in the size of the models, but rather from identifiable differences in physical assumptions. Moreover, at present there is little reason to trust the larger models more. All such models (at least in the current literature) predict that a doubling of CO_2 will lead to a global warming between 1.5° and 5°C.[17] This is the basis for item 4. As we have already noted such predictions are incompatible with the small value of the past increase in temperature claimed in item 5. We have further seen that the data hardly support even this claim. Finally, the model result that such warming as was predicted to have occurred over the last hundred years should be strongest in the arctic is directly contradicted by the observed cooling trend in this region.

At this point, there would normally be a strong impetus toward discovering what was wrong with our models. Efforts along these lines are, indeed, in progress. The notion that there are likely to be serious problems in existing computer simulations of the climate is not at all surprising within the meteorological and oceanographic communities. Models commonly have difficulty reproducing well observed major features of the current climate (mean global temperature, the pole to equator temperature difference, the intensity and position of the jet stream, seasonally averaged regional variations of climate, etc.) without what is euphemistically referred to as 'tuning.' In 'tuning,' processes that are not resolved by the model are parameterized in such a manner as to bring the model into agreement with what are believed to be the observations. Models used for climate predictions are usually somewhat primitive versions of the models used for weather prediction. Problems have also been observed with weather prediction models, though the situation has certainly been improving. The most likely area to search for severe problems is in the interaction of climate with water (in all its phases). The remarkable thermodynamic properties of water almost certainly lead to its acting as nature's thermostat. Yet in the major numerical models, all feedbacks between warming and water are positive. In the absence of these positive feedbacks, these same models would yield warmings (due to doubling of CO_2) only 1/4 to 1/7 of those in item 4. When it is recognized that at least some of these feedbacks are likely to be negative rather than positive, it is easy to see that the actual response to a doubling of CO_2 may readily be 1/8 to 1/14 – or even less – of what is suggested in item 4. These are by no means ideal or eccentric suggestions. For example, we have already noted that the net observed effect of lay clouds is to cool the atmosphere. In models, while warming leads to increased cloud cover, the net effect is to amplify the warming. The modeling of cloud cover is a delicate and uncertain effort; modellers admit doing a poor job of it. Still modest improvements can lead to dramatic results. The British Meteorological Office climate model had predicted a 5° warming accompanying a doubling of CO_2. A few weeks ago, they reported that the simple matter of correcting the liquid water content of layer clouds had reduced this value to 2°C – a reduction of 60%! Another problem of comparably large magnitude may prove easier to correct. In all the large numerical models, about two thirds of the warming associated with the doubling of CO_2 is actually due to the fact that in the models, warming is associated with increasing water vapor at all levels.[18] Recall that water vapor is a far more important greenhouse gas than is CO_2. Recall, as well, that convection significantly short circuits the greenhouse absorption below about 5 km. Greenhouse absorption is primarily important above 5 km. Now, the existing climate models are notoriously bad at predicting upper level water vapor. While warming does increase water vapor near the ground in nature, warming is also associated with more and deeper cumulus convection. This is known to lead to drying of the upper troposphere[19] (above 5 km). The nature of this drying effect, which is omitted in current climate models, is illustrated in Figure 7.

This cumulus convection occurs in deep towers of rapidly rising air. The air cools as it rises, and the water vapor in the air condenses and falls out as rain. By the time these clouds top out (at altitudes as great as 16 km), they are relatively drained of water vapor. Of course, one can't have these rapidly rising towers of air without compensating air subsidence almost everywhere else, and this subsidence acts to fill the atmosphere above about 3-5 km with dry air. Figure 8 illustrates the effects of warming on this process. We see that warming leads to drying of the atmosphere above 5 km (as opposed to the moistening which occurs in current models); it also leads to the elevation of the altitude at which convected heat is deposited. The latter effect increases the extent to which convection short circuits greenhouse absorption. Both effects are negative and not positive feedbacks to CO_2 heating. These, will act to diminish the effect of CO_2 warming rather than magnifying it by a factor of three as occurs in present models. My guess is that this correction alone will diminish estimates of CO_2 warming by a factor of about six, but careful studies of this matter will probably not be completed for another year or so.

The above hardly exhausts the possible sources of error in present models. However, it suffices to show that the possibility of large overestimates is very real. Consistent with past data, one may reasonably expect that corrected models may very well end predicting greenhouse warmings of only a few tenths of a degree Centigrade.

These, then are my reasons (and those of others) for believing that greenhouse warming will be much smaller than current publicized estimates. I personally think it very unlikely that we will see more than a few tenths of a degree Centigrade from this cause over the next century – a magnitude that will continue to be masked by natural variability. No one can absolutely guarantee that the effect won't be larger, but I think the likelihood to be very small that a great warming will arise from man's intervention. It should be added that I am in no position (nor is anyone else) to guarantee that the earth won't get significantly warmer or cooler; it certainly has done so in the past. Indeed, our climate has been both warmer and colder than at present solely due to the natural variability of the system. External influences are hardly required for such variability to occur.

Where then does the scientific consensus that people in public life are so enthusiastic about arise? This is an interesting question, and says much about the interaction between scientists and the public. Clearly, it is even hard for scientists to evaluate such problems as potential global warming – especially if their expertise is not in climate, oceanography and atmospheric physics. Within these fields, one is dealing with only a small number of active research scientists. Even amongst these, how is the public to distinguish between conflicting claims? Among scientists, there is, in principle, a commitment to objective assessment. One tests theories by trying to design measurements that will distinguish amongst them. One tests data by checking it against such fundamental constraints as may exist. (This unfortunately, is highly dependent on the availability of both funds and scientists to conduct such tests; the amount of the former and the number of the latter are both becoming uncomfortably limited.) One does not as a rule, depend on votes. This is not a procedure with much attraction to most public figures. The public, therefore, seeks out representatives for science who will report to the public on what are presumed to be legitimate scientific inquires.

The selection of such representatives has a certain arbitrariness, since scientists rarely select or endorse such representatives. What happens more commonly is that scientists elect officers of scientific societies (such societies need officers for obvious non-scientific reasons), and the public conveniently assumes these officers to be representatives. University presidents and department chairpersons occasionally serve a similar role. Many other representatives are self appointed. Though I do not pretend to speak for my colleagues, there is some self-evident danger that in writing this article, I am falling into this last category. In this country, the premier organization that is asked to represent science is the National Academy of Sciences (which together with the National Academy of Engineering and the Institute of Medicine sponsor the National Research Council). The National Academy consists of about 1500 members who are elected on the basis of their scientific accomplishments. Election to the Academy is considered a high honor. When, however, the Academy responds to an inquiry, it does so through committees of the National Research Council. Oddly enough, there is only minuscule representation of Academy members on these committees (approximately 6%). Thus the connection of so called National Academy reports to the Academy itself is tenuous and uncertain. In principle, these reports are reviewed by academicians, but the selection of these reviewers is fairly arbitrarily handled by the NRC staff and the Presidents of the Academies of Science and Engineering and the Institute of Medicine. As a member of the Academy, I have never felt that there is any malicious intent in these procedures; they simply represent a rather casual accession to bureaucratic convenience. Still there is a gnawing feeling that there is an issue of 'truth in labelling' here.

As concerns the problem of global warming, NRC 83 asserts that there is general agreement that increases in infrared absorbing gases will contribute to warming. It is acknowledged that there is substantial uncertainty in the magnitude of the expected warming, but it is also noted that existing models have for the last ten years or so, all predicted warmings in a similar range (1.5°C - 5°C). As we saw earlier in this paper, these predictions are disturbingly inconsistent with records; moreover, all the models (including one that I published[20]) shared common errors. This tendency for scientists to reproduce each other's errors is not at all uncommon – especially when one recognizes that models are subject to 'tuning;' scientists are hardly resistant to human failing. Nevertheless, Frank Press (President of the National Academy of Sciences) and Robert White (President of the National Academy of Engineering) did informally poll many of us on this issue. The question asked was, "Did we agree that increased CO_2 would lead to warming?" Most of us, including myself, did agree, hence, perhaps the claimed consensus. Still science, to be science, must be quantitative, and there is a world of difference between a warming of .2°C and a warming of 4°C. The former has virtually no policy implications since it is undetectable; the latter would be very important indeed. Why then do scientific representatives obscure this fact? Certainly, the great enthusiasm of journalists and politicians for scientific unanimity is a not so subtle influence.

There is, however, another reason for the easy acquiescence of so many scientists. Namely, most of the policy implications resulting from assuming that the warming is significant seem benign. Many of us feel that a more thoughtful energy policy would be a good thing quite apart from the potential warming. More caution in our approach to deforestation is hard to criticize. Freeman Dyson commenting on 'nuclear winter,' suggested that it was bad science but good politics. But, is it really benign to invoke bad science on behalf of causes that certainly can stand on their own? I think not. Science is a crucial and advantageous tool for society only as long as it preserves its integrity. It seems pointless to sacrifice this for causes that hardly require such a sacrifice. Moreover, there is no assurance that the policy implication of ill-based environmental warnings is inevitably benign. The banning of freons, and their replacement by generally inferior, more expensive, and potentially as harmful products is a case in point. The ozone issue is, however, a separate and comparably complex issue that deserves a separate discussion.

Finally, one must ask why politicians have become so insistent on scientific unanimity on environmental issues – especially when the policy implications are independently virtuous? Here, I am venturing well beyond any expertise that I may pretend to. Nevertheless, as a scientist and as a citizen, the issue is important to me, and I will attempt a guess. Central to contemporary politics seems to be the matter of building constituencies. Energy conservation seems to have proven rather small and ineffective in this regard. On the other hand, saving 'mother earth' seems both high minded and effective. It is interesting to note in this regard the almost universal preference of the verb 'save' to more accurate verbs like 'protect,' 'improve,' 'preserve,' etc. Presumably, 'save' suggests a more ominous – though invisible – crisis, and presumably, crises are politically more effective. Both the temptations and dangers of such an approach are obvious. Initially, the politicians need the scientists' assent that 'mother earth' needs saving, but as passions mount and the issue assumes the role of a religion, dissent will become tantamount to heresy.[21]

To be sure, things have not yet come to this point. However, either through ignorance or intent, conditions are arising which impede the needed scientific exploration of this problem. In popular, but serious articles,[22] lip service is paid to 'scientific uncertainty,' but the nature of the uncertainty is so profoundly distorted as to virtually eliminate the role of scientific inquiry. What is done is to claim scientific consensus for the notion that increases in minor greenhouse gases will lead to a large and intolerable warming; the uncertainty as to physical processes is held to be mostly taken care of by the oft repeated range of prediction of 1.5°C - 5°C. The main 'uncertainty' is held to be largely restricted to the ability to detect this warming in the record of observed temperature. It is then argued that thirty years or more of observations will be needed before the observations will unambiguously display the trend. It is finally argued that by the time thirty or more years have passed, it will be too late to save our planet. Thus, we must act now to curb severely the introduction of any minor greenhouse gases into the atmosphere. In support of this view, Jonathan Schell quotes Stephen Schneider, who describes what he refers to as the 'scientists' dilemma.' He points out that scientists as scientists are committed to the truth, but that as 'human beings' desirous of a 'better world,' they must "offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might have" in order to get 'loads of media attention' and thereby 'capture the public's imagination.' Schneider describes this as a 'double ethical bind,' and concludes with the hope that scientists can manage to be both 'effective' and 'honest.' Still, the overall tenor of his remarks is that the humane and ethical position is to ignore the science and act now. Indeed, it sometimes appears that the litmus test of public morality has become the willingness to act out of ignorance. 'Scientific uncertainty' is relegated to the role of excessive fussiness. I personally believe that scientists can only be effective by being honest. The so-called 'double ethical bind' is not only an unconscionable attack on the role of science, but also an attack on the seemingly lost ideal of the practice of democracy by an educated citizenry. As we have seen, the real uncertainty is far greater than has been stated – and extends to the question of whether significant warming is to be expected at all. Although science can never be totally free of uncertainty, there is research that can and must be done in order to improve our basic physical understanding of how the global climate actually functions. It is maliciously specious to suggest that thirty years or more would be needed to substantially reduce uncertainty. Within less than a decade we could sufficiently improve our understanding of convection, cloud cover, ocean chemistry, ocean dynamics, etc. so as to make our predictions vastly more meaningful. None of this is facilitated by assuming the answer to begin with and committing ourselves to ill thought out actions. While uncertainty can never be eliminated, and prudent care is usually worthwhile, prudent care cannot be permitted to give way to an intolerance of any risk whatever. Real mischief will be unavoidable. Given a week or so, I would have no difficulty generating a long list of environmental problems that although objective, would be exceedingly unlikely cannot be rigorously proven impossible. If each called forth a statutory response, our society would be quickly paralyzed – tied into excruciating knots by its well meaning but misplaced enthusiasm. Any power base that is built on such an enthusiasm would hardly serve the nation in a way that any of us would wish.

FOOTNOTES

1. *Democrate*, Fall 1989, p. 5.

2. These matters are reviewed in a manner adequate for our purposes in *Changing Climate - Report of the Carbon Dioxide Assessment Panel*, a report of the Board on Atmospheric Sciences and Climate of the National Research Council published by the National Academy Press in 1983. We shall refer to this report as NRC 83.

3. The radiative and photochemical process of the middle atmosphere *Middle Atmosphere Dynamics*, Academic Press, New York 489 pp. 1987. The coupling of temperature and ozone is formulated in Lindzen, R.S. and R.M. Goody, *J. Atmos.Sci.*,*22*, 341 (1965).

4. NRC 83 *ibid*, Hansen, J., E. Johnson, A. Lacis, S. Lebedeff, P. Lee, D. Rind, and G. Russell, *Science*, 313, 957 (1981).

5. The issue of 'natural' variability is far more serious than is commonly stated. In a review of the recent Workshop on Greenhouse-Gas-Induced, Climatic Change [R.A. Kerr, *Science*, 244, 1041 (1989)], there was almost no mention of one of the most interesting findings: namely, that almost all models, when run for long periods of about 100 years, exhibited variability unrelated to greenhouse warming that was as large or larger than the greenhouse induced warming itself. The variability found in nature seems to be smaller than that found in the models, but still swamps anticipated greenhouse effects. The precise origin of natural variability is still uncertain, but it is not all that surprising. Although the solar energy received by the earth-ocean-atmosphere system is relatively constant, the degree to which this energy is stored and released by the oceans is not. As a result, the energy available to the atmosphere alone is also not constant.

6. An excellent review of global climate date is given in Ellsaesser, H.W., M.C. MacCracken, J. J. Walton and S. L. Grotch, *Rev. Geophys.*, 24, 745 (1986).

7. Newell, N.E., R.E. Newell, J. Hsiung, and Wu Zhongxiang, *Geophys. Res. Letters*, 16, 311 (1989).

8. Karl, T.R., R.G. Baldwin, M.G. Burgin, *Time series of regional season averages of maximum, minimum, and average temperature, and diurnal temperature range across the United States*: 1901-1984, 107 pp (1988) (Available from National Climatic Data Center, Federal Building, Asheville, NC 28801.)
Hanson, K., G.A. Maul, and T.R. Karl, *Geophys, Res. Letters*, 16, 49 (1989)
Karl, T.R., H.F. Diaz and G. Kukla, *J. Clim*, 1, 1099 (1988b)
Bolling, R.C. and S.B. Idso, *J. Geophys, Res.*, 94, 3359 (1989)

9. The references for these figures are:
   - Ellasaesser, H.W., et al., ibid.
   - Jones, P.D., S.C.B. Raper, R.S. Bradley, H.F. Diaz, P.M. Kelly and T.M.L. Wigley, *J. Clim. Appl. Meteorol.*, 25, 161 (1986a).
   - Jones, P.D., S.C.B. Raper, B.S. Sauer, B.S.G. Cherry, C. Goodess, R.S. Bradley, H.F. Diaz P.M. Kelly, and T.M.L. Wigley, *A grid point surface air temperature data set for the northern hemisphere, 1851-1984, Tech. Rept.*22, Carbon Dioxide Division, U.S. Dep. of Energy, Washington, D.C. (1986b).
   - Slutz, R.J., S.L. Lubker, J.D. Hiscox, S.D. Woodruff, R.L. Jenne, D.H. Joseph, P.M. Seurer, and J.D. Elms, COADS *comprehensive ocean atmosphere data set; Release 1,* US DOC

Climate Research Program, Environ, Res. Lab., Boulder, CO (1985).

- Ramage, C.S., *J. Clim. Appl. Meteorol.* 23, 187 (1984).
- Folland, C.K., D.E. Parker, and F.E. Kates, *Nature,* 310, 670 (1984).
- Karl, T.R. et al., (1988a) ibid.

10. Hansen, J. and S. Lebedeff, *J. Geophys. Res.,* 92 13,345 (1987).

11. Rogers, J.C. in *Proceedings of the Thirteenth Annual Climate Diagnostics Workshop,* 170 (1989). (Prepared by the National Oceanic and Atmospheric Administration, and available from National Technical Information Service, Department of Commerce, Sills Building, 5285 Port Royal Road, Springfield, VA 22161). According to Kerr's review ibid, a model being run by Washington and Meehl is displaying arctic cooling. The observed cooling amounts to about 0.5°C between 1960 and the present. In terms of climate, this is a fairly significant cooling – especially in comparison with the expected warming.

12. A relatively simple treatment of traditional greenhouse notions is given in J.T. Houghton, *The physics of atmospheres,* 203 pp, Cambridge Univ. Press, Cambridge (1977).

13. Ramanathan, V., B.R. Barkstrom, and E.F. Harrison, *Phys. Today,* 42, 22 (1989).

14. This fact is not always clear in schematic depictions of the earth's surface energy budget.
Figure 6 [from MacCracken and Luther, editors, *Detecting the climatic effects of increasing carbon dioxide, Rep.* DOE/ER-1235, U.S. Dept. of Energy, Washington, DC (1985)] would suggest that the surface cools jprimarily by infrared emission. The diagram shows an outward infrared flux from the surface that greatly exceeds the latent heat flux (i.e., the cooling due to evaporation). However, the same figure shows the atmosphere reemitting a large infrared flux back to the surface. It is the difference between these fluxes that represents the actual surface cooling due to infrared emission. In the limiting case where the atmosphere is totally opaque to infrared radiation this difference goes to zero. This is almost the situation in the tropics.

15. Möller F., and S. Manabe, *Z. für Met.,* 15, 3 (1961).

16. Lindzen, R.S., A.Y. Hou, B.F. Farrell, *J. Atmos. Sci.,* 39, 2416 (1982).

17. Reasonably current reviews of climate modelling may be found in papers by M.E. Schlesinger and by M.E. Schlesinger and J.F.B. Mitchell in M.C. MacCracken and F.M. Luther, ibid.

18. Manabe, S. and R.T. Wetherald, *J. Atmos. Sci.,* 37, 99 (1980).

19. The drying effect of cumulonimbus convection is well known to specialists in cumulus convection:*viz* Arakawa, A. and W.H. Schubert, *J. Atmos. Sci.*, 31, 674 (1974), Geleyn, J.-F., C. Girard and J.-F. Louis, *Beitr. Phys. Atmosph.* 55, 325, (1982).

20. Lindzen, R.S., A.Y. Hou, and B.F. Farrell, ibid.

21. Clearly, I am greatly understating the complexity of the political and social situation. Energy issues are not alone in molding the current response to the long term awareness of the possibility of global warming. Gro Harlem Bruntland, Norway's prime minister, in an interview with the *San Francisco Chronicle* (April 9). 1989), expressed the hope that environmental affairs will replace the Cold War as the main framework for international affairs. Similar remarks have been made by other major world leaders. The move of the Union of Concerned Scientists away from nuclear disarmament to prevention of global warming as their focus mirrors the replacement of disarmament by the environment as an issue for conveniently expressing a high degree of public morality. Environmental organizations (including profit making environmental information services) have not been slow to recognize that fear of global warming is an effective aid to fund raising. Political scientists, international affairs experts, lawyers, and others have found the possibilities of international environmental politics irresistible – especially as concerns global warming.

22. McKibben, B., 'Reflections (The End of Nature)', *The New Yorker,* p. 47, September 11, 1989. Schell, J., 'Our Fragile Earth,' *Discover,* 10, 44 (1989).

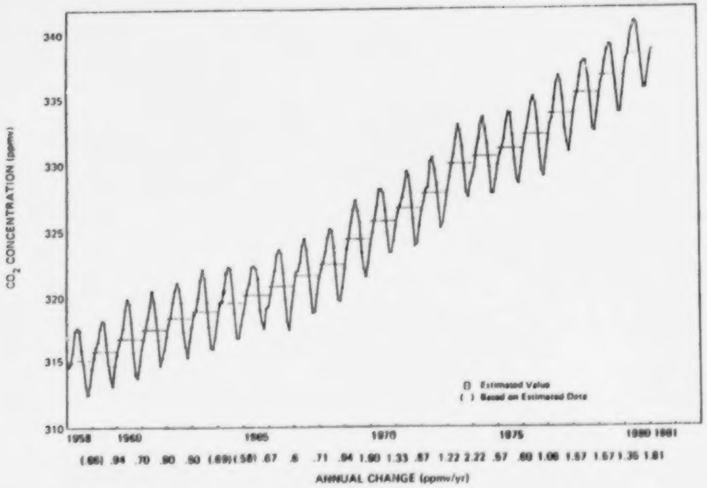
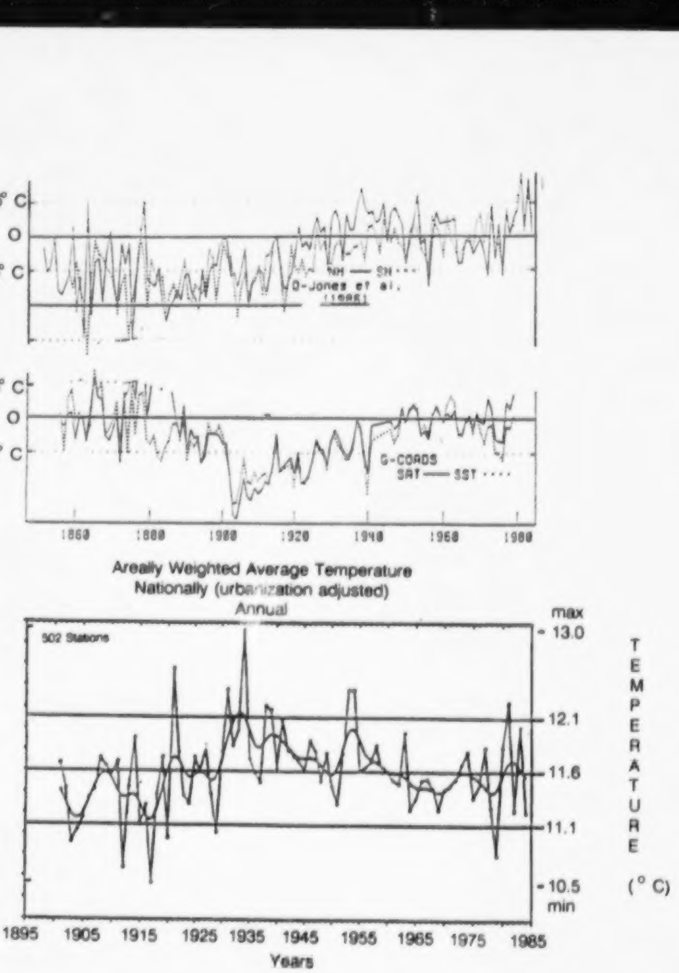


FIGURE 1. Mean monthly concentrations of atmospheric CO2 at Mauna Loa. The yearly oscilllation is explained mainly by the annual cycle of photosynthesis and respiration of plants in the northern hemisphere. See Section 1.2.2 for discussion of annual cycle. (Source: Geophysical Monitoring for Climate Change, National Oceanic and Atmospheric Administration.)



Top curves: Annual mean temperature departures from 1951 - 1970 normals derived from station data. The solid curve represents northern hemisphere data; the dotted curve represents southern hemisphere. The average between the two tends to be somewhat smoother than either curve. Reproduced from *Ellsaesser, et al, 1986* who analyses from *Jones, et al, 1986 a, b*[19].

Middle curves: Annual mean temperature departures from 1951 - 1970 normals derived from ship data for air temperature (solid line) and sea surface temperature (dotted line). Reproduced from *Ellsaesser, et al, 1986* based on analyses of *Slutz, et al, 1985, Ramage, 1984,* and *Folland, et al, 1984*[20].

Bottom curves: Annual mean temperature areally weighted over the contaguous 48 states. The solid curve represents a 9-year running smoother. Reproduced from *Karl, et al, 1988*[21].

FIGURE 2

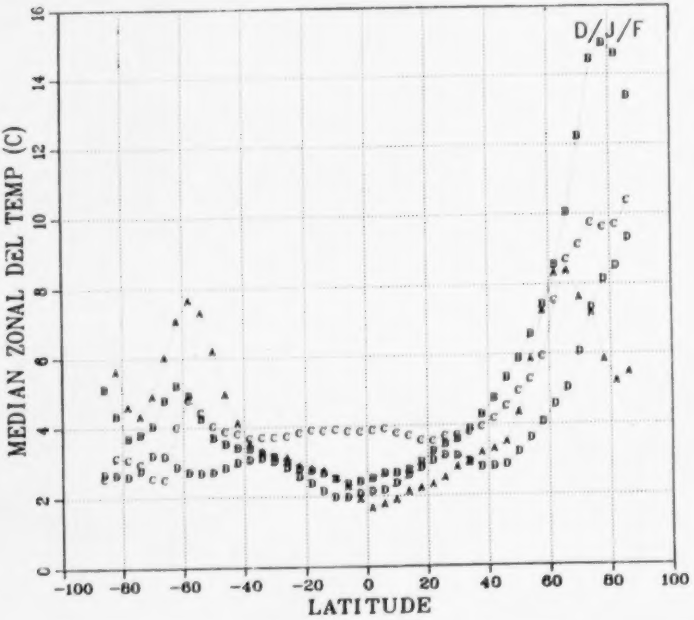


FIGURE 3. Superposed medians for the four GCMs of the zonal distributions for the predicted change in surface air temperature due to a doubling of CO_2 for DJF (A = CCM, B = GFDL, C = GISS, D = OSU).

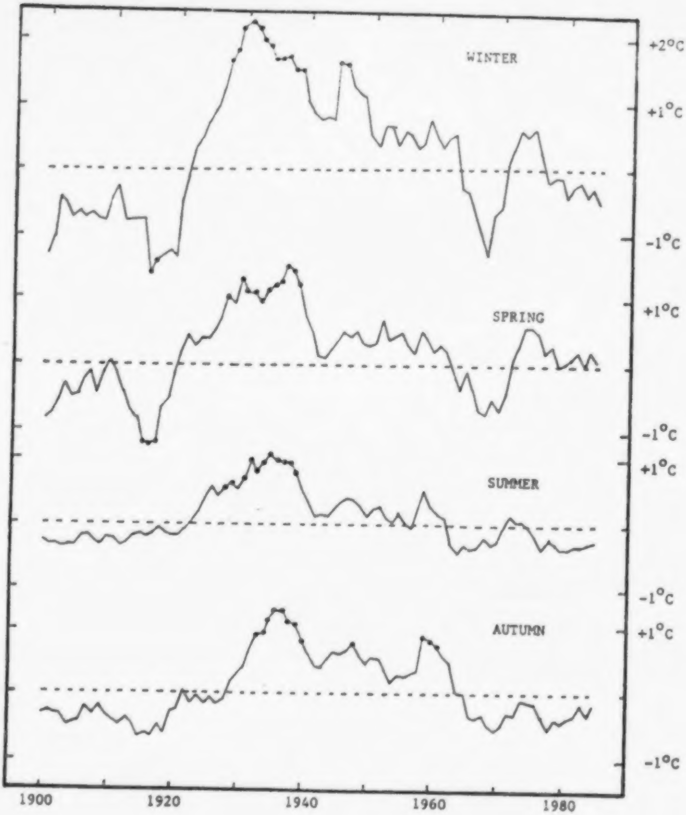
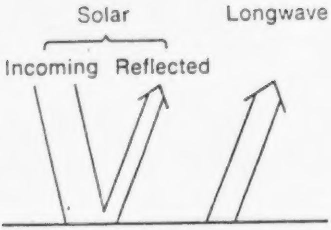
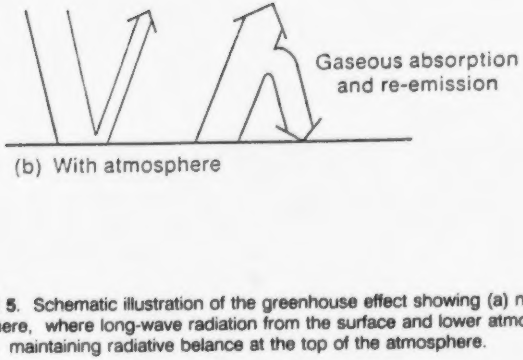


FIGURE 4. Five year averages of seasonal temperature anomalies over the Atlantic Arctic since 1900. Dots indicate five-year means temperature anomalies which are significantly above or below the 1881 - 1987 mean using the Cramer t-test. Temperatures are plotted on the middle year of the five-year means.



(a) No atmosphere



(b) With atmosphere

FIGURE 5. Schematic illustration of the greenhouse effect showing (a) no atmosphere, where long-wave radiation from the surface and lower atmosphere, and upward, maintaining radiative belance at the top of the atmosphere.

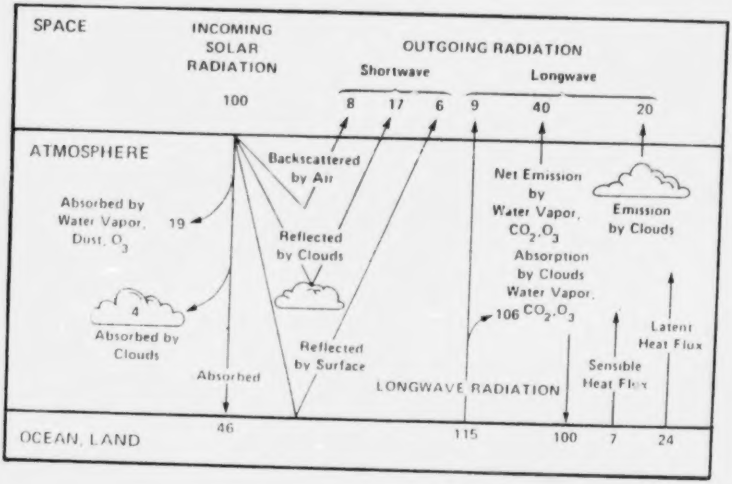


FIGURE 6. Schematic representation of the atmospheric heat balance. The units are percent of incoming solar radiation. The solar fluxes are shown on the left-hand side, and the longwave) thermal IR) fluxes are on the right-hand side (from *MacCracken and Luther*, 1985).

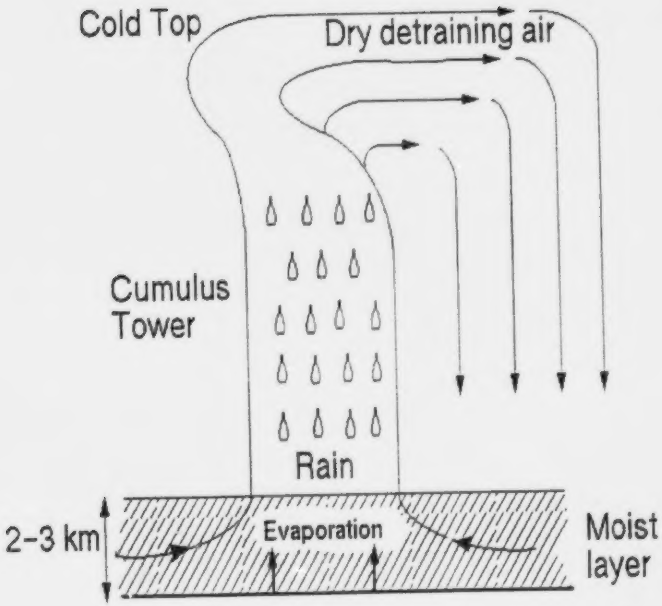
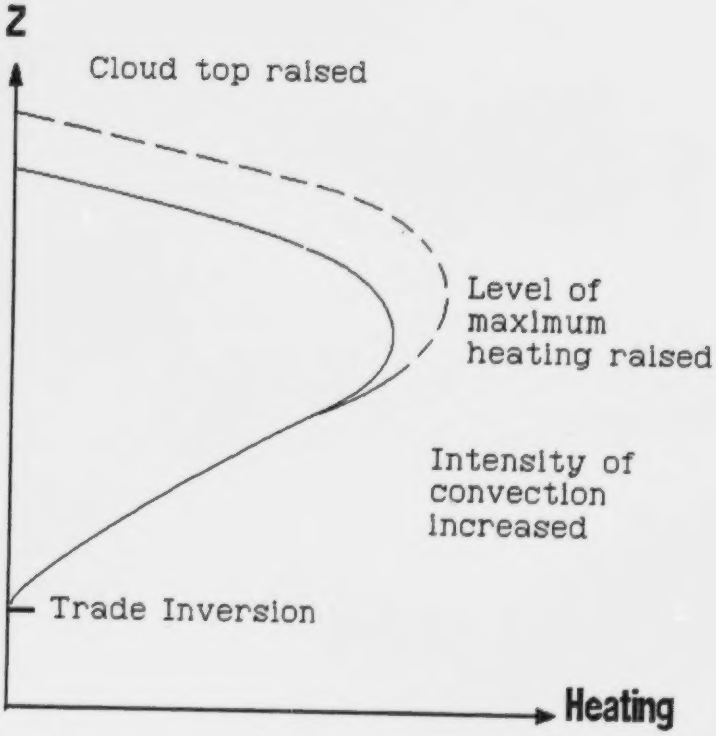

Cold Top
Dry detraining air
Cumulus Tower
Rain
2-3 km
Evaporation
Moist layer

FIGURE 7


Z
Cloud top raised
Level of maximum heating raised
Intensity of convection increased
Trade Inversion
Heating

1. Raising cloud top means that detrained air is dryer.
2. Increased intensity means that dryer air is pushed down more effectively.
3. Increased level of maximum heating means that heat is radiated through less absorber.

FIGURE 8

IMPROVED CLIMATE MONITORING FOR DETECTING GLOBAL CLIMATE CHANGE

Henry F. Diaz
National Oceanic and Atmospheric Administration
Environmental Research Laboratories
Boulder, Colorado

The need to provide an adequate observational capability in order to monitor the global climate system for the effects of increasing atmospheric greenhouse gas concentration has been underscored in a series of recent reports and articles. Dr. Robert M. White, writing in the Bulletin of the American Meteorological Society (September 1989) states that, "Improving the information base to reduce uncertainties in our data, in our projections, and in our understanding of consequences would seem to be a sine qua non"..."This means investment in improved understanding of physical processes so that they can be modeled more accurately, intensified examination of climate data bases, improved assessments of projected emission rates of greenhouse gases, and improved space and ground based monitoring systems."

We should remember that the paradigm guiding the investigation of all geophysical phenomena, proceeds in the following order: Starting with Observation of natural processes we attempt to Understand the system (development of hypothesis, models, etc.). This then leads to Prediction (testing of models against observation, etc.), and only after enough knowledge is accumulated through this process, does one proceed to assess the possible consequences, and, if necessary, to develop control and adjustment strategies.

Scientific consensus on detection of climate change induced by increasing atmospheric concentrations of radiatively active trace gases hinges principally on two issues, namely, the capability of current state-of-the-art climate models to define the greenhouse-gas-induced signal, and on the adequacy of climate data to enable the identification of a statistically and physically significant signal of changes in the earth's climate. Other points to consider are that a change in climate is as much a problem of definition as detection, since it depends on the two time intervals selected for comparison. Given that climate is a statistical description of a mean state, our understanding of climate change depends on the availability, quality, temporal extent, areal coverage, and the interpretation of such data in terms of what they imply about the climate. As an example of this, Figure 1 (at end of paper) shows one record of surface temperature deviations for Northern and Southern Hemisphere land areas since the 1850s. One interpretation of this record is as shown by the smoothly increasing best fit curve, i.e., one of slowly increasing surface temperatures. A closer look at these curves, however, reveals that significant departures from the general upward trend occur lasting from several years to decades. One could just as easily interpret the results by proposing the existence of two background states: one prevailing before the 1920s and one after (Figure 2). Ideally, we would wish to have a long period of observations to decide whether recent climate behavior departs significantly from past behavior. Figureures 3 and 4 show the results of plotting 20-30 year means of the Northern Hemisphere temperature curve shown in the previous two figures. The data are deliberately plotted at the end of 900 year abscissa to illustrate the relative brevity of the instrumental record. From this perspective, the interpretation of the record would suggest one more akin to that shown in Figure 2 (i.e., the existence of two climate regimes with a transition period around the 1920s.)

Numerical models of greenhouse-gas-induced climatic change indicate that high latitude regions should experience the greatest increases in surface temperature. Figure 5 shows temperature variations in approximately 30-year increments for the latitudinal belt 50°N to 85°N and for two sectors within this zone. Besides mirroring changes illustrated in previous figures, it is obvious that the recent changes have tended not to be zonally symmetric. This suggests changes in the configuration of the planetary scale atmospheric circulation in this region. The changes associated with different seasons of the year (Figure 6) also exhibit different trends. The situation calls for caution in assigning cause and effect to past changes. Since climate itself is highly variable, detecting climatic changes (as distinct from natural fluctuations) will be a difficult task. Therefore, attributing a particular change in this system to a particular forcing mechanism among many other interacting mechanisms requires a much more detailed understanding of climate processes than we have at present.

The drought and heat wave of 1988 and the attendant disruptions and economic hardship to various sectors of the national economy highlighted the issue of anthropogenic modification of climate and brought the issue to the forefront of national and international policy agendas. A look at U.S. precipitation variations during the past 90 years (Figure 7) indicates a large amount of year to year variability. Since 1972, national precipitation had been considerably above normal. The low values of 1988 appear to be quite a normal swing, with similar occurrences having been recorded several times during this period. In fact, just a few years back, the concern was about too high a level in the Great Lakes and in other large lakes such as the Great Salt Lake (Figure 8).

The following critical issues are noted regarding our global climate monitoring capabilities. There has been a major decline in the available quantity of station records since the late 1970s. Due to a variety of reasons ranging from spatial representativeness to changes over time in observing practices and instrumentation, it is difficult to separate climate signal from climate noise. This means that we do not know at present, whether recent climatic patterns are the result of climatic change, or part of the natural variability of climate, which is known to be quite large. This is also due, in part to the fact that the period of record for instrumental observations is generally too short to define that "natural" variability. Recent numerical model simulations of climate change using coupled ocean-atmospheric concentrations. Those results also suggest caution in interpreting recent data in the context of the so-called equilibrium model results.

Below, I have listed some elements of a comprehensive strategy for monitoring some important climate indicators.

Changes in Precipitation: Determine if there are changes in the spatial and seasonal distribution. It is important to determine if a shift in the precipitation zones is occurring or whether the amplitude of the annual cycle is changing. Assess the evidence for trends or other shifts in annual averages, in the variance and in other statistical characteristics compared to historical records. Analyze changes in the frequency distribution of extreme events.

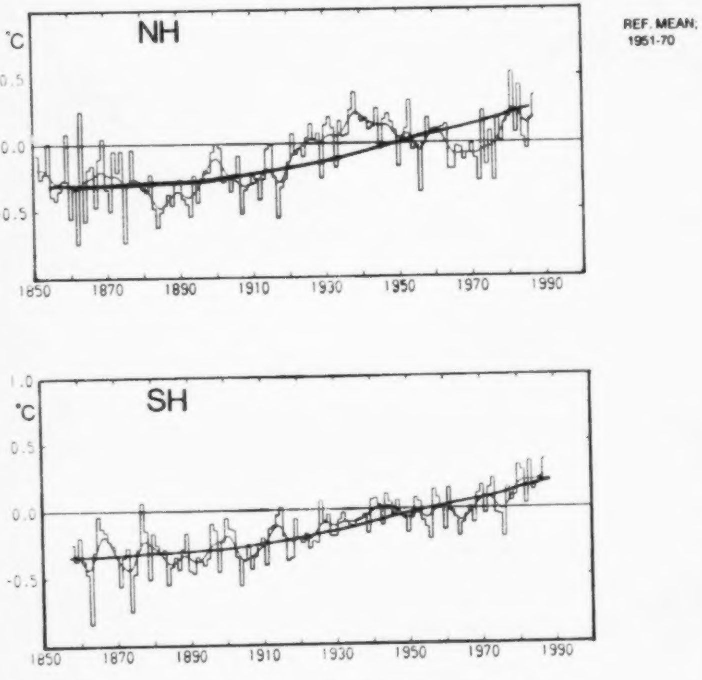
Changes in Temperature: Assess latitudinal, longitudinal and vertical differences of temperature change, as well as seasonal differences and how they square with theoretical expectations. Ascertain changes in the frequency of occurrence of extreme events such as heat waves, cold waves, etc.

Other monitoring efforts could be aimed at detecting whether such anomalous short-term climatic fluctuations as drought and wet spells, and of such destructive phenomena as tornados and hurricanes display changes in their frequency of occurrence or in their intensity.

Finally, I have outlined below what I consider to be present critical observational needs. For climate monitoring purposes, a long baseline of high quality records is critical. An important attribute of such data is that it provide continuous well-documented measurements of the principal climate variables (surface temperature, precipitation, etc.). Efficient access to these data is also very important. Upgrading of computer resources and making optimal use existing observational systems, improving data communication and greater consideration for climatological needs in the operational weather forecasting environment is needed.

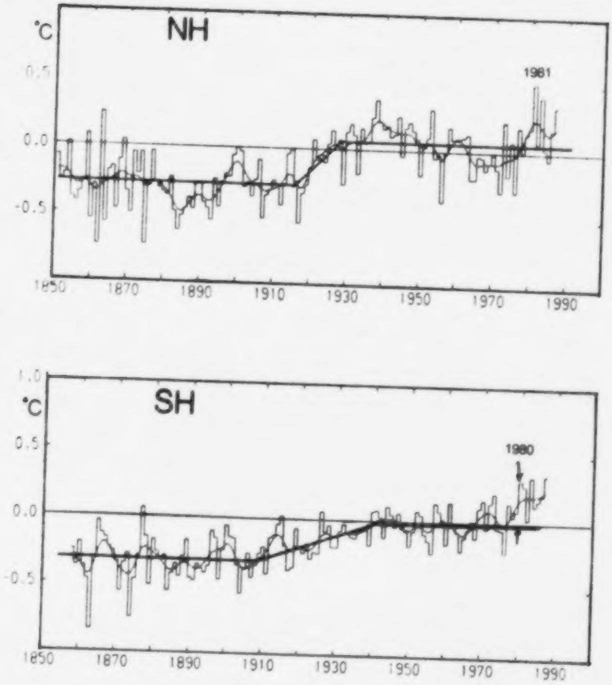
Robert White noted that the U.S. (and other countries as well) find themselves in, "a classic dilemma of policy formulation--Possibly severe but unknown levels of risk of undesirable consequences of climatic change in the face of great uncertainty about causes, costs and consequences." In this uncertain environment, he notes that policy principles would suggest, "investment in improving the information base to reduce uncertainties so that policy actions could be based on improved understanding; and adoption of policies . . . that address causes and predicted consequences in such a way that future options are not foreclosed if projections turn out to be incorrect . . ."

As noted at the outset, such prudent investment represents a very small fraction of the potential consequences of implementing any response strategy.



Land-based annual mean surface air tamperatures for the Northern Hemisphere (upper) and Southern Hemisphere (lower).

Figure 1



Land-based annual mean surface air tamperatures for the Northern Hemisphere (upper) and Southern Hemisphere (lower).

Figure 2

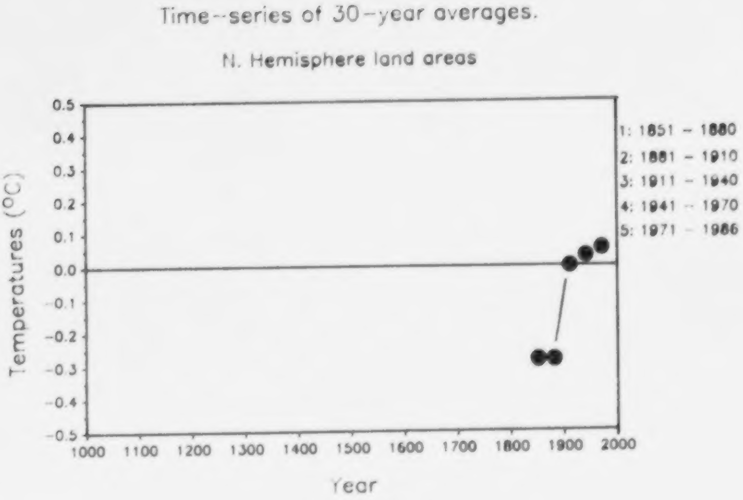


Figure 3

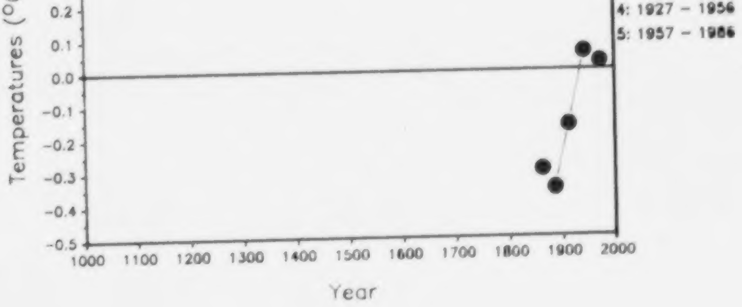
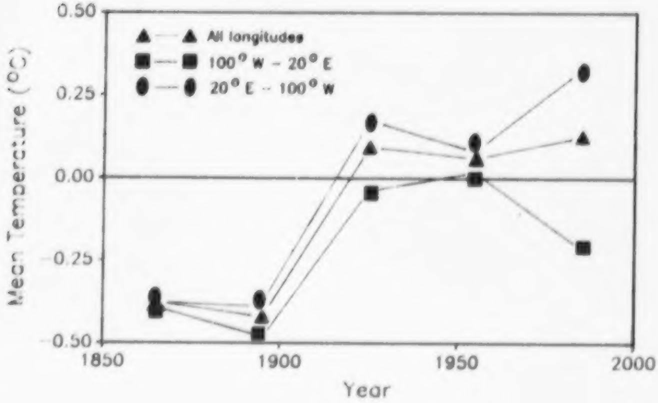


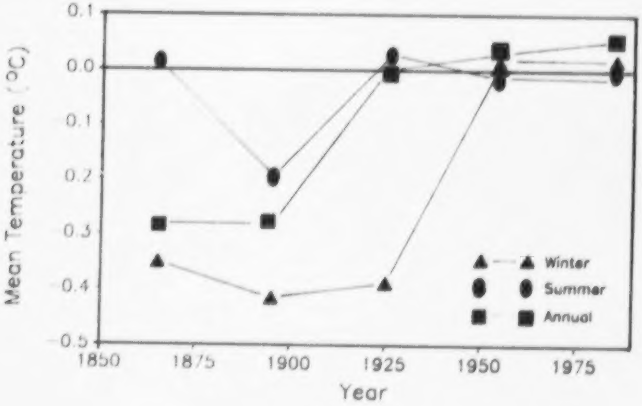
Figure 4



30 year Temperature means, 50N – 85N

Northern Hemisphere Land Areas, starting 1851.

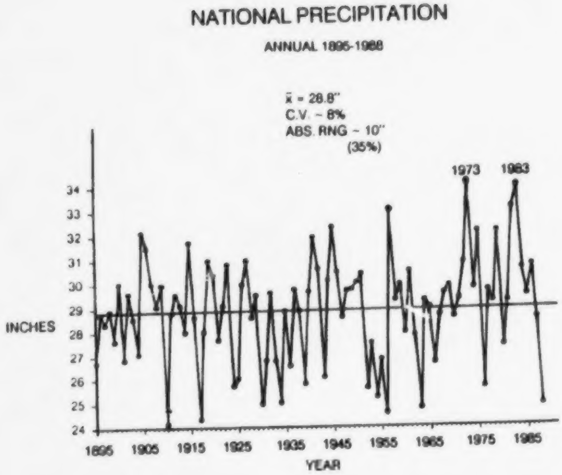
Figure 5



30 year means of Northern Hemisphere Land area Temperature

1851 – 1987

Figure 6



Graph of area-weighted precipitation for the contiguous United States. From Weekly Weather and Crop Bulletin, Vol. 76, No. 3, Jan 24, 1989.

Figure 7

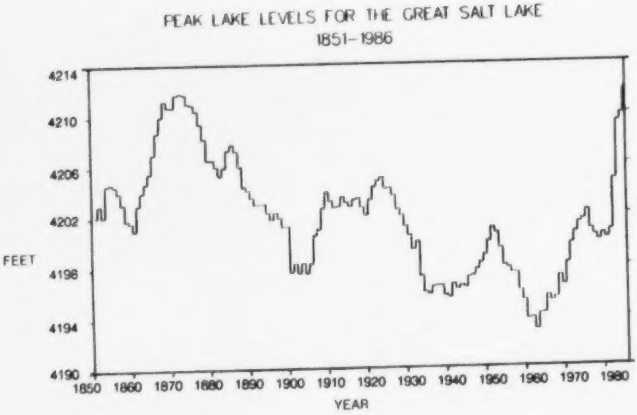


Figure 8

V. STRATEGIES TO MINIMIZE ENVIRONMENTAL DAMAGE

ROLES OF ENERGY EFFICIENCY IN REDUCING ENVIRONMENTAL IMPACT

William W. Schertz, Manager
Conservation and Renewable Energy
Energy Systems Division
Argonne National Laboratory

INTRODUCTION

The theme of this year's energy conference is the environmental impact of energy production. I would like to discuss the role of energy efficiency as a viable means of reducing environmental impact. Although it may seem obvious that improved energy efficiency decreases the environmental impact, this paper will try to provide some quantitative data on the magnitude of the effect that has been demonstrated and what may be expected in the future; in particular, what technologies can be brought to bear to increase energy efficiency and decrease environmental impact.

To put the numbers in perspective, first consider that saving one quad of energy through increased efficiency will eliminate the need to burn 470,000 barrels of oil per day for an entire year. When multiplied by the total number of quads that can be saved by advanced, energy-efficient technologies, this can become a significant reduction in the consumption of fossil fuels.

I have used the term "energy efficiency" in preference to "conservation" because the objective is to produce more gross national product (GNP) with less energy, not to "do without."

Improved efficiency has already made a significant contribution to the nation's energy supply picture. Figure 1 shows the energy use in the United States from 1960 to 1985.[1] It is very interesting to note that the energy use in 1985 was the same as in 1973. If the trend of energy use increase that preceded 1973 had continued, we currently would be using 32 quad more energy than we actually used. This would translate to 15,040,000 barrels of oil per day equivalent.

What led to such a dramatic change in the energy use trend? Clearly the shock of higher oil prices was a key factor, and the economy moved to more energy-efficient methods of doing the same jobs. Not all of the energy savings were because of improved efficiency; some of the change was due to a shift in the type of activities, for example, a move from manufacturing toward service industries. About half of the change was due to efficiency improvements.

Figure 2 shows the growth in our energy productivity (GNP/million Btu) since 1972.[1] We have made significant gains. We currently produce 35% more GNP unit energy, have 20 million more houses, and have 50 million more vehicles on the road than in 1973. Part of the GNP rise is due to the change in mix of services provided, but about 50% is due to the increased efficiency of energy use.

Energy use in the United States is divided about equally between three sectors: transportation, buildings, and industry (Figure 3). Some examples of the savings that can be made in these sectors will be outlined in the balance of this paper.

TRANSPORTATION SECTOR

There have been impressive efficiency gains in the transportation sector (Figure 4).[2] The largest gains were made by the airline industry, as they converted to more efficient and larger planes. The passenger car industry made significant gains, and the truck industry made smaller gains. The U.S. Department of Energy's Office of Transportation Systems has estimated that improved materials (i.e., ceramics) and design may reduce year-2010 projected transportation energy requirements by 3-7 quad.

What are some of the areas in the transportation sector that could be expected to make additional gains? Cconsider that there is a wide variety in the level of technology that is currently applied in the automotive industry. One can currently purchase a V-8 engine with 2 valves per cylinder that produces 145 hp. At the other extreme, a 4-cylinder engine with 4 valves per cylinder and turbocharger can produce the same power at full throttle, but it will be much more efficient than the V-8 at partial throttle.

In the rail/airline portion of the sector, there have been some interesting studies at ANL that considered the use of magnetically levitated, high speed trains to link major airports with smaller airports in a hub-and-spoke arrangement. The airports serve as terminals for both the airlines and the high-speed trains, but the train supplies the transportation to nearby cities (for example, Chicago-St. Louis, or Chicago-Detroit), while the airlines provide the service to more distant locations. This removes the necessity of having so many short-haul airline flights from the major airports and still allows rapid city-to-city transport. Such a system could, if implemented, significantly reduce the congestion in the sky over major airports. Furthermore, the high-speed train is more energy-efficient and more weather-independent than the airplane systems that it would replace.[3]

BUILDINGS SECTOR

In the buildings sector, there have been some substantial improvements in the technology available to the consumer. Furnaces of less than 92% efficiency are readily available now, as compared to 60-70% efficient units that were available in 1973. Research is in progress to make thermally activated heat pumps that will use the gas energy more efficiently, giving the equivalent of 150-160% when compared to the high-efficiency furnaces of today.

Home designs have improved to the point that very-low-energy-use homes can be built on a regular basis. At least one developer in the Chicago area sells homes in which he guarantees a heating bill of less than $200/year or he pays the difference. Unfortunately, many of the homes being built by the majority of the builders ignore these advances or only apply a small percentage of the techniques. Much needs to be done to convince the buying and building public of the availability and applications of these design techniques.

Another area in which technology can have a major impact is in the development of improved lighting. Solid-state ballasts that run standard fluorescent tubes at a higher frequency will increase the light output per watt of electricity by about 25%. Over two million solid-state ballasts are in use nationwide, annually saving over 200 million kilowatt-hours of electricity. These electronic ballasts, currently installed in a less than 3% of the fluorescent fixtures, are expected to penetrate the market to 50% by 1995.

Improved windows can have a major impact on energy savings. In 1973, the bulk of the windows being installed in a single-family residences were single-glazed, which gives an R-value of about one. Double-glazed windows (R = 2) have largely replaced single glazing in new construction, and now the use of low-emissivity (low-E) coatings on the glass surfaces has raised the R-value to 3-4. Windows under development include an interior membrane and an inert, low-conductivity gas fill that will raise the window to R = 6-10, at which point the window can be a net energy gainer in all parts of the country. Figure 5 shows the configuration of these windows.

INDUSTRIAL SECTOR

Although substantial progress has been made in the industrial sector, we clearly can do much better. Table 1 shows a comparison of the energy efficiency of the United States and various competitors. In the United States, the total primary energy requirement per unit of gross domestic product dropped from 0.76 in 1973 to 0.56 in 1987. The fact that we have improved substantially since 1973 is the good news. The bad news is reflected in the fact that we have not reached the levels that have been obtained by the other countries, i.e., they have improved also in the past 15 years and are still more energy-efficient than the United States. This can be viewed as an"energy tax" that affects our competitiveness in the foreign markets. We currently use almost twice the energy/GDP that Japan uses.

Table 1. Total Primary Energy Requirements/Gross Domestic Product for Selected Countries

Country	1973	1987	Average Annual Growth Rate (%) 1973-1987
Germany	0.38	0.30	-1.7
Italy	0.36	0.28	-1.8
Sweden	0.43	0.39	-0.5
Japan	0.41	0.28	-2.7
Netherlands	0.44	0.36	-1.7
United Kingdom	0.44	0.33	-1.9
Int'l Energy Agency Total	0.56	0.43	-1.9
United States	0.75	0.56	-2.3

Some of the areas in which we are developing new technology include improved sensors and controls, variable-speed controls for motors and heat pumps, improved catalysts and biocatalysts, advanced separation processes for the chemical and food industries, and advanced processes for the steel industry. The effect of developments currently being addressed could reduce the year-2010 projected requirements by 5.7 quad.

ACKNOWLEDGMENT

This work was supported by the U.S. Department of Energy, Assistant Secretary for Conservation and Renewable Energy, under contract W-31-109-Eng-38.

REFERENCES

1. Klan, M.S., et al. Energy Use and Conservation Trends 1972-1986. Pacific Northwest Laboratory Report PNL-6714 (1989).

2. Transportation Energy Data Book: Edition 9. Oak Ridge National Laboratory Report ORNL-6325 (1987).

3. Johnson, L.R., et al., Maglev Vehicles and Superconductor Technology: Integration of High-Speed Ground Transportation into the Air Travel System. Argonne National Laboratory Report ANL/CNSV-67 (1989).

4. Estimated Energy Savings in U.S. Industry Achievable through R&D, 1987-2010. Prepared for the Office of Industrial Programs, U.S. Department of Energy by Energetics, Inc., Washington, D.C. (1987).

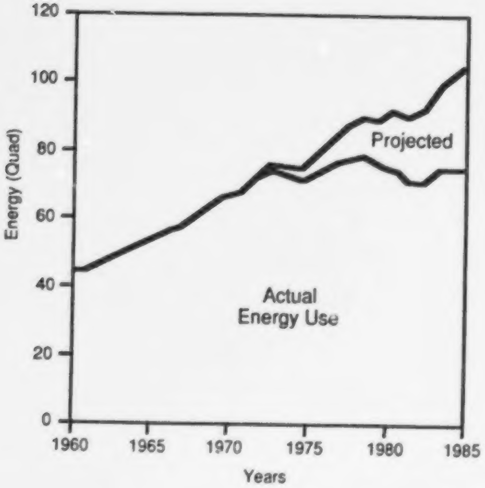


Figure 1 U.S. Energy Use since 1960

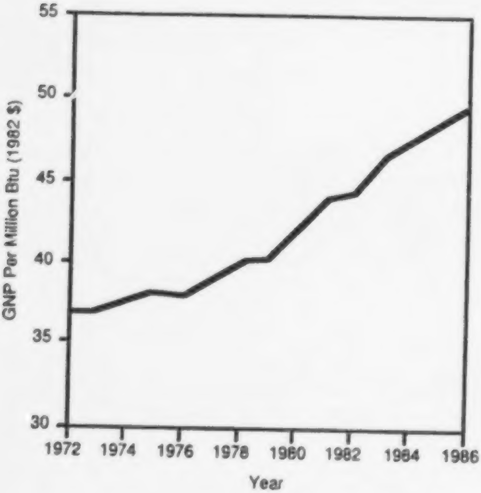


Figure 2 U.S. Energy Productivity since 1972

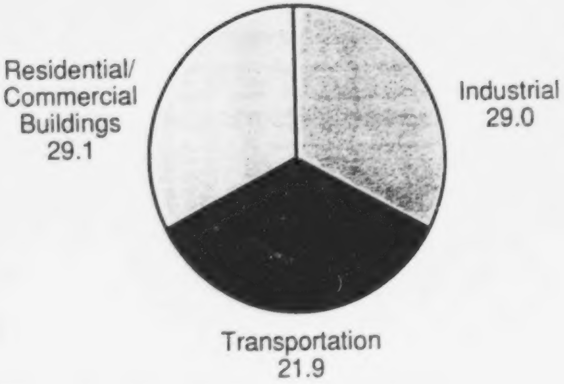


Figure 3 U.S. Energy Use by Sector (in quads)

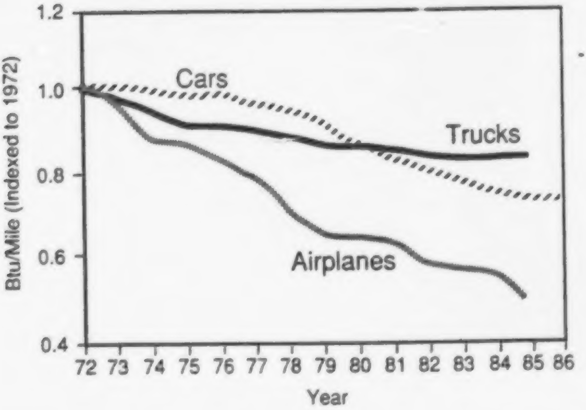


Figure 4 Energy Use Efficiency in the Transportation Sector

Current Window Designs

- R-2 double glazing
- R-3 double glazing with low-E coating
- R-4 double glazing with low-E coating and gas fill

Future Window Design: High-R Super Windows

- R-6 to R-10 high-R glazing
  - example:
    R-8 insulating glass using two low-E coatings and a 90% Krypton/10% Argon gas fill

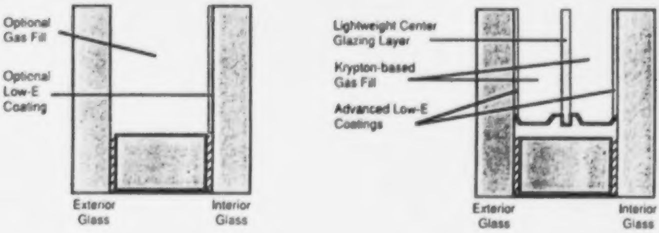


Figure 5 Current and Future Window Designs

STRATEGIES FOR COMBATING URBAN POLLUTION

Jerrold L. Levine
Director Corporate Studies
Amoco Oil Company

INTRODUCTION

With the reauthorization of the Clean Air Act currently undergoing debate at the federal level it is necessary to revisit the objectives of the original Clean Air Act and the progress made since its passage.

Amidst mounting environmental awareness in the U.S., the Clean Air Act was adopted in 1970. The act established numerous air quality goals for several different criteria pollutants and also set automobile and stationary source emission standards designed to improve the nation's ambient air quality.

Since 1970, reductions in air pollutants have been achieved across the board – airborne lead is down nearly 95%, sulfur dioxide, precursor to acid rain, down 17%, carbon monoxide and particulates reduced 25 and 23 percent respectively and ozone has declined by more than 17 percent. The number of exceedances of the air quality standards is down even more than the absolute level of emissions.

All industries have had a hand in bringing about these changes - utilities with new clean coal technologies, auto maker's shift to more fuel efficient and lower emitting vehicles and the oil industry's phase-out of lead in gasoline and more recently the addition of oxygenates and reduction of reid vapor pressure to address ongoing carbon monoxide and ozone concerns.

Yet, despite industry efforts and the spending of over $30 billion annually for environmental controls, more than 100 cities across the country continue to be out of compliance with the national ambient air quality standard for ozone.

While it is clear that the strategies employed to date have made an impact, more can and should be done to bring these remaining areas into attainment of the ozone standard. Before exploring the remaining control options available to combat ozone, it is important to understand the nature of the ozone problem. Ozone is formed when hydrocarbons react with nitrogen oxides in the presence of sunlight. While emissions of hydrocarbons and nitrogen oxides occur fairly uniformly throughout the year, ozone is generally only a problem during the hot summer months. And then only when the right meteorological conditions occur to cause the air to stagnate over a period of days.

Hydrocarbon emissions originate from many sources – both stationary and mobile. Stationary and area sources consist of factories, refineries, dry cleaners, bakeries and service stations among others. As a group, this category comprises more than sixty percent of all summertime man-made emissions. Outside of the large factories and refineries, controls have generally not been placed on the other numerous stationary/area sources because it traditionally not been viewed as cost effective (Figure 1).

Mobile sources represent the balance of all man-made sources. Consisting of both motor vehicles and the fuels used to power them, these sources may be regulated under several different control strategies. Generally, mobile source controls may affect the vehicle, the fuel or a combination of both. Beginning with the automobile, limits on tailpipe exhaust emissions have proven to be the single most effective control strategy. Since 1970, more than 95% of all automobile emissions have been eliminated because new cars have been designed to run leaner, catalytic mufflers have been used to convert exhaust gases and manufacturing specifications have been tightened to reduce evaporative leaks (Figure 2).

While new cars have been certified as 95% cleaner than pre-control days, a problem still exists with the millions of cars already in the vehicle fleet. It is generally accepted that 8 to 10 percent of the vehicles generate 50% of all the pollution. These vehicles have come to be known as gross polluters. While they may span all types and model years, gross polluters are typically older vehicles. In recognition of this, states have initiated inspection and maintenance programs to better insure that all in-use vehicles are operating properly.

Controls that may impact either the vehicle or the fuel are regarded as refueling controls. While emissions generated during refueling are much lower than those from automobile tailpipes, they represent an important part of a mobile source control strategy. While both on-board canisters and stage II refueling controls are technically sound, the issue of which option to employ has been mired in politics.

With new vehicles controlling more than 95% of all pollutants, attention has recently shifted to the fuels these vehicles operate on. The summer of 1989 saw several states and the federal government regulate gasoline volatility for the first time. Indications are this emphasis will continue as the U.S. EPA moves to initiate the second phase of its volatility program for the summer of 1992. Many states will undoubtedly follow suit with their own controls.

While the Clean Air Act deals with several of the more traditional control options, the new area of concern for the Bush Administration has become alternative fuels. Under the Bush plan, the nine urban areas with the nation's worst ozone problem would be required to replace a portion of their vehicle fleets with new vehicles that operate on clean alternative fuels. While several fuels have been advanced as candidates, those generally regarded as the most probable are methanol, reformulated gasoline and compressed natural gas (CNG).

Neat methanol's major benefit is that, in optimize vehicles, it may potentially lower vehicle hydrocarbon emissions by 90% from conventional gasoline. In addition, at 107 octane, engines may be designed to take advantage of the power and its clean burning characteristics through an optimization of the compression ratio. The problems center on the transition period - currently there are only about 500 methanol vehicles on the road today, several of which have recently been recalled due to engine and fuel system problems. Consequently, to make methanol work would require a major leap in technology. This is likely to come at great expense because there is no infrastructure in place to supply methanol fuel. Current worldwide methanol production is approximately 7 billion gallons. Most of this is used by the chemical industry with some going to the production of MTBE, a gasoline component. To supply the requirements of President Bush's original plan would require an incremental production capacity of 12 billion gallons annually by the year 2004. The capital cost alone to build the manufacturing facilities would be over $15 billion dollars (Figure 3)

Finally, methanol is produced from natural gas and since most of the world's supply of cheap gas lies outside the U.S., this represents an energy security and balance of payments problem as well.

Like methanol, a reformulated gasoline also offers reduced vehicle emissions, although per vehicle reduction is likely to be less than that for optimized methanol vehicles. Nevertheless, since a reformulated gasoline would apply to all in-use vehicles, rather than a portion of new vehicle sales, the cumulative emissions reduction is much larger than may be obtained with methanol. And since the infrastructure is already in place to supply gasoline - refineries, pipelines, ships, trucks and service stations - the cost of reformulating gasoline should be more modest, on the order of 5 to 10 cents per gallon.

While reformulated gasoline holds the most promise in providing substantial long-term air quality benefits, little research has been done to date to indicate what the final formulation will be. Both Arco and Sun have announced their environmental gasoline plans and the auto and oil industries have recently announced a joint research program designed to identify future fuel characteristics. However, it will be a few years before definitive results are known. The fuel that offers the most immediate air quality benefit is compressed natural gas (CNG). Comparable to neat methanol in optimize vehicles, CNG reduces hydrocarbon emission by 90 percent and yet is competitively priced with today's gasoline. Furthermore, since the U.S. has substantial natural gas reserves, it also provides energy security. Compressed natural gas is rated at 130 octane and may be used to optimize vehicle engine performance, thus enabling it to be marketed alongside premium gasoline (Figure 4 & 5).

Despite these benefits, CNG is not without its own pitfalls. Foremost among them is vehicle range. Currently, CNG vehicles are only able to travel approximately 100 miles between refuelings, compared to 300 miles for conventional gasoline. While this performance is expected to improve with better CNG tank design, it presently is a significant market barrier. Similarly, the placement of the CNG fuel tank, in the passenger compartment or vehicle trunk takes up space and is viewed as a drawback to broad scale development. And finally, while supplies of natural gas are plentiful, with fairly extensive pipeline and distribution networks, little else is available in the way of infrastructure to market CNG. Conventional service stations would need to be reconfigured and compressors installed at a cost of approximately $250,000 per facility. Likewise, converting existing automobiles to operate on CNG requires an investment of roughly $1,500 per vehicle. New vehicles can be manufactured for about $200 more per vehicle.

Figures 6 and 7 provide a closer examination of the economics of CNG. Retail gasoline at $1.00 per gallon is equivalent to $8.70 per million BTU (MMBTU). Current residential natural gas prices are approximately $3.80 per MMBTU, significantly less than gasoline. However, the capital investment required to manufacture a CNG vehicle, either as original equipment (OEM) or retrofit must be factored into the equation. Similarly, the cost of installing the compressor and pumping facilities at the retail outlet also must be included. Figure 7 provides a comparison of all the cost components on cents per gallon gasoline equivalent basis.

The column on the far left approximates the components of the current retail price of unleaded regular gasoline, while the center and right columns show the comparable data for CNG as original equipment manufacture and conversions. Fuel cost reflects the wholesale cost to the service station operator including applicable excise and motor fuel taxes. For CNG, power cost represents the electricity charge of operating the compressor facility. Capital charge, present under each case, includes applicable costs of pumps and piping and for CNG vehicle as well as the cost of the compressor. The last line, other, captures all other related costs and associated dealer margin, which for illustrative purposes is assumed to be the same for both gasoline and CNG. In total, under original equipment manufacture, compressed natural gas would cost essentially the same as current gasoline. While

retrofitting vehicles cost approximately 18 cents per gallon more, this cost is still competitive with today's premium gasolines.
Recently, I had the opportunity to travel to Vancouver, British Columbia to observe its CNG program. Vancouver's experience covers the gamut of possible applications – from light duty gasoline cars and trucks to transit buses and semi-tractors. Of the light duty vehicles, several fleets are in operation. We visited two Black Top Cabs that operate approximately 160 retrofitted Oldsmobiles through a single centrally located compressor station, and the other, Pacific Press Delivery Vans, operates a fleet of newspaper delivery vehicles. Both fleets have experienced excellent performance records and have found that the incremental capital cost has been more than recovered in fuel and maintenance savings in as little as two years (Figure 8).

The city of West Vancouver, while operating all its municipal fleets on CNG, including police squad cars, snow plows and garbage trucks, has had the most success with its transit buses. These busses are capable of operating on either CNG of diesel fuel without any degradation in performance.

Of the 9,000 vehicles currently operating on CNG in Vancouver, 4,500 of them are private passenger cars, all of which have been retrofitted at cost of approximately $1,500 per vehicle. Refueling is accomplished through 40 retail gasoline facilities throughout the city, which like gasoline requires approximately three minutes to complete. The newest technology to capitalize on passenger car conversions is the development of home compressors. These units cost $1,500 apiece and tap into the existing residential natural gas supply line and fill passenger vehicles slowly while parked overnight.

The wide range of applications and the success Vancouver has had in implementing its CNG program has become a model for future programs in the United States. In light of the on-going concerns over air quality and energy security, this represents a new approach to combatting urban pollution.

Air Pollution Sources

Stationary/Area
- 60% of Man-Made
- Numerous Sources

Mobile
- Fuel and Vehicle Sources
- Control Strategies

Figure 1

Mobile Source Control Strategies

Automobile
- Inspection and Maintenance
- Tailpipe

Either/Or
- Refueling Controls (Canister/Stage II)

Fuel
- Gasoline Volatility
- Alternate Fuels

Figure 2

Alternate Fuels

Methanol

- Low Emissions
- Powerful Fuel
- Refueling Problem (FFV Transition)
- Cost/Energy Security

Reformulated Gasoline

- Less Emission Benefit Per Vehicle
- Applies to All In-Use Vehicles
- Use Existing Infrastructure

Compressed Natural Gas (CNG)

Figure 3

Compressed Natural Gas

Benefits

- Low Emissions
- Cost
- Energy Security
- Powerful Fuel

Problems

- Vehicle Range
- Tank Location
- Infrastructure

Figure 4

CNG Economics

Natural Gas Price

Current Retail Gasoline	$1.00/gallon $8.70/MMBTU
Current Residential Natural Gas Price	$3.80/MMBTU

Fixed Cost

CNG Vehicle:	OEM	$ 200/ea
	Conversion	$1,500/ea

Service Station Compressor, Pump, etc.	$150,000 - 250,000

Figure 5

CNG Economics

	Gasoline	CNG OEM $200 Ea.	CNG Conversion $1500 Ea.
Fuel Cost (Incl. Taxes)	0.90	0.54	0.54
Power Cost	-	0.07	0.07
Capital Cost	0.06	0.34	0.52
Other*	0.15	0.15	0.15
Total	1.11	1.10	1.28

*Includes Transportation, Dealer Margin and Other Costs

Figure 6

Hydrocarbon Emissions, Grams/Mile

	Evap.	Refueling	Exhaust	Total
Gasoline, New	0.34	0.07	0.53	0.94
M85	0.11	0.05	0.15	0.31
M100	0.00	0.00	0.05	0.05
CNG	0.00	0.00	0.05	0.05
Gasoline, Current	0.83	0.20	0.70	1.73

Figure 7

Vancouver Experience

- Car/Light Truck Fleets
  - Black Top Cabs
  - Pacific Press Delivery Vans
- Heavy Duty Vehicles
  - City of West Vancouver Transit Buses
- Passenger Cars
  - 4,500 Vehicles
  - 40 Retail Outlets
- Home Compressors
  - $1,500 Cost
  - Slow Fill

Figure 8

ENVIRONMENTAL ALTERNATIVES FOR TRANSPORTATION

Timothy L. Sprik
Emission Control Technology Division
U.S. Environmental Protection Agency

This paper reviews options and opportunities in the transportation arena. Before delaying with some of the specific technical options that are under consideration, however, I would first like to take a few moments to put the transportation industry in the proper perspective. For most of us, transportation is an important part of our daily life. Currently, roughly 30 percent of the energy we consume is used for transportation. Along with the many benefits that transportation brings us, however, come some serious environmental concerns.

I am sure you are all aware that ozone is one of our most serious urban air quality problem. Ground-level ozone has been shown to impair lung function and damage lung cells. Unfortunately, a large number of our nation's cities are not in attainment with ozone standards, and many will not reach compliance without additional stringent control programs.

Ozone is not emitted directly, but is a product of a series atmospheric reactions involving hydrocarbons and nitrogen oxides. Motor vehicles are important sources of both hydrocarbons and nitrogen oxides, and our motor vehicle emission control program has achieved considerable success in reducing these pollutants. Compared to an uncontrolled passenger car in the 1960's, a car produced today will emit approximately 80 percent less hydrocarbons and 60 percent less nitrogen oxides during its lifetime. Unfortunately, however, much of this impressive per vehicle emissions reduction has been offset by the continual growth in the number of motor vehicles and the number of miles these vehicles travel (Figure 1 at end of the paper).

EPA believes that for most urban areas hydrocarbon control is the most promising strategy for reducing ozone levels (in some areas, EPA encourages nitrogen oxide reductions as well). Even with the large emissions reductions of the last two decades, motor vehicles still account for 30 to 50 percent of all urban hydrocarbon emissions (Figure 2). Any comprehensive solution to our widespread ozone problem must involve major reductions in vehicle hydrocarbon emissions.

A second important urban air quality problem is toxic air pollution. Toxic air pollution involves a large number of different compounds emitted by a variety of sources. Data recently released by EPA indicate that 2.7 billion pounds of toxic chemicals are emitted into the air each year. We estimate that these emissions contribute to approximately 1500 to 3000 fatal cancers annually. Air toxins also can be associated with respiratory disease and birth defects. Motor vehicles account for approximately 50 percent of all toxic air emissions (Figure 3). The most important air toxins from vehicles include particulate matter, benzene, and butadiene.

There are a number of transportation options available for mitigating our urban air quality problems. First, there are several control programs that can begin to take effect almost immediately. These include further control of gasoline volatility, the use of oxygenated fuels, improved inspection and maintenance programs, the control of refueling emissions, and the use of clean alternative fuels in transit buses. Second, there are several regulations that we will be able to promulgate fairly quickly but that won't begin to provide major emissions reductions until the mid 1990s. These include, for example, tighter vehicle tailpipe standards, improved evaporative emission controls, and off-highway vehicle emission standards.

Some cities, however, will need a third major step in reducing hydrocarbon emissions in order to ultimately comply with our ozone standard. And with gasoline vehicle emission controls that will be approaching the technological limit, we really will only have two basic options. The first would be to remove the automobile from the environment by putting restrictions on automobile use in certain areas. The second option would be to reconcile the automobile with the environment by switching from petroleum to inherently cleaner fuels. We believe that the latter is much preferable to driving restriction.

There are several vehicular fuels that are inherently cleaner than gasoline, such as methanol, ethanol, natural gas, propane, and electricity. Electric vehicles are a special case, since they do not require internal combustion engines on-board the vehicle and emission depend on the feedstock and emission controls used at the electric power plant. For the other fuels, methanol, ethanol, natural gas, and propane, we project that each of these fuels could provide an 80 percent or greater reduction in hydrocarbon emission relative to a future gasoline vehicle meeting stringent future emission standards. These large emission reductions are due to two primary reason. First, each of these fuels yields inherently low evaporative hydrocarbon emissions -- methanol and ethanol because of extremely low volatilities and natural gas and propane because they are stored in sealed fuel tanks on-board the vehicle. Second, the hydrocarbon emissions from these fuels, almost exclusively in the exhaust, are much less photochemically active, i.e., much less likely to form ozone, than hydrocarbon emissions from gasoline vehicles.

These fuels also would provide large reductions in air toxins emissions as well, on the order of 90 percent of more relative to gasoline vehicles. The major toxic pollutants from gasoline include benzene, 1,3--butadiene, gasoline POM and refueling vapors. Cleaner fuels such as methanol, ethanol, natural gas, and propane would to a large extent eliminate these concerns.

The clean alternative fuels program recently proposed by the Administration is a major step toward bringing these clean fuels into the transportation arena and reconciling the automobile with the environment. The program requires that metropolitan areas with ozone levels of 50 percent or more above our ozone standard be included in the clean alternative fuels program. Based on the most recent ozone data, the following nine cities would be included: Los Angeles, Houston, New York City, Milwaukee, Baltimore, Philadelphia, Hartford, San Diego, and Chicago (Figure 4). Automobile manufacturers would be required to sell 500,000 clean alternative-fueled vehicles in 1995, 750,000 such vehicles in 1996, and 1,000,000 clean alternative-fueled vehicles in each year from 1997 through 2004. Vehicles would qualify as clean alternative-fueled vehicles if their emissions met the emissions performance standard that would be established by a formal rulemaking process. Once emission performance levels are established, industry is allowed to meet the standards in the most cost-effective manner, by developing any combination of engine and fuel. Based on consultation with the automotive manufacturers and the States, EPA would then require fuel availability at all high-volume service stations in the nine cities (Figure 5). In addition, EPA would retain the authority to extend the fuel availability requirement to major nationwide corridors if necessary to support vehicles that would be dedicated to clean alternative fuels.

In a separate requirement, clean alternative fuels would be phased-in for new transit buses in metropolitan areas of 1,000,000 population or more based on the following scheduled: 10 percent of sales in 1991, 25 percent of sales in 1992, 60 percent of sales in 1993, and 100 percent of sales in 1994 and later model years.

The size of this program has been designed to be large enough to permit economies of scale to be utilized in vehicle and fuel production, but not so large as to cause economic dislocations. For example, by 1997 clean alternative-fueled vehicles would account for over seven percent of nationwide automobile and light truck sales, and for approximately 30 percent of sales in the affected urban areas. Fuel demand would not grow so rapidly as to diminish petroleum demand, however. Even in the affected cities, clean alternative fuel demand would simply offset growth that would otherwise occur in petroleum demand. Thus, no refineries would be put out of business (Figure 6).

Of course, we recognize that there could be some consumer reluctance in the early years, so the program has been designed to minimize consumer concerns. The program will permit the use of flexible or dual-fuel vehicles in the yearly years. Those vehicles will look and perform just like gasoline vehicles and will therefore be "invisible" to consumers. Consumers will have absolute assurance of convenient clean alternative fuel availability, just as they did with the successful transition to unleaded gasoline in the 1970's (Figure 7). The combination of the federal requirement for high-volume service stations to provide clean alternative fuel for sale and the State's requirement to ensure that use of the fuel is economic for the consumer should give the public complete confidence. Further, because of the sales requirement, the automobile manufacturers will have every incentive to design, promote, and price clean alternative-fueled vehicles in a manner so as to ensure proper sales volumes.

In closing, I would like to say a few words about EPA's perspective on the merits of the different clean alternative fuels. Some have criticized EPA for being "pro-methanol" and the clean fuels program for being a "methanol mandate." This is simply just not true. The clean fuels program is fuel neutral and any fuel that can meet our emission performance standards will be eligible. EPA supports the use of any fuel that can provide real world emission reductions in a manner that is cost effective and acceptable t the driving public. Whether that clean fuel is electricity, ethanol, methanol, natural gas, propane, reformulated gasoline, or any other, I believe all of us who support clean air should work together to make a strong clean alternative fuels program a reality. Otherwise, none of us will get anywhere. And I assure you that EPA will continue to carry out our responsibilities in a fair and objective manner. Our air quality and public health are too important to do otherwise.

What Are We Up Against?

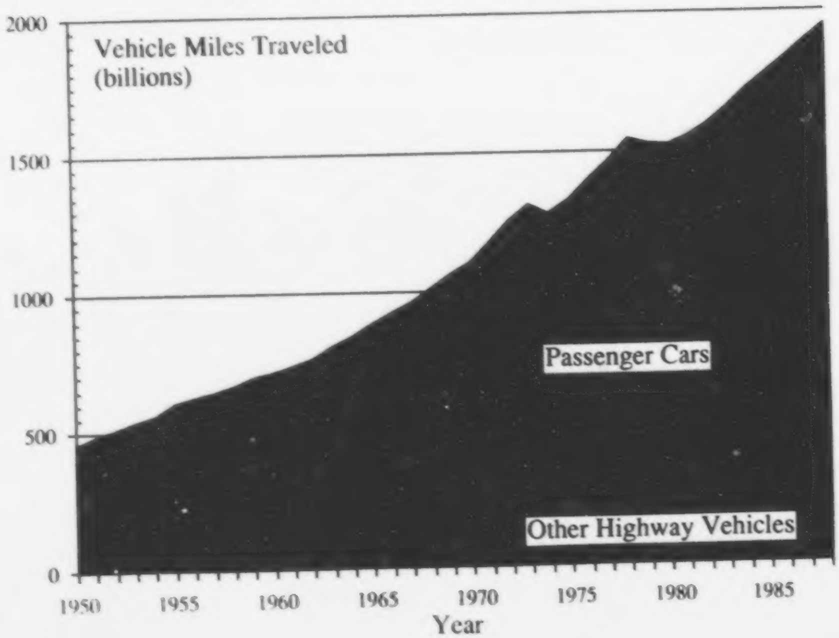
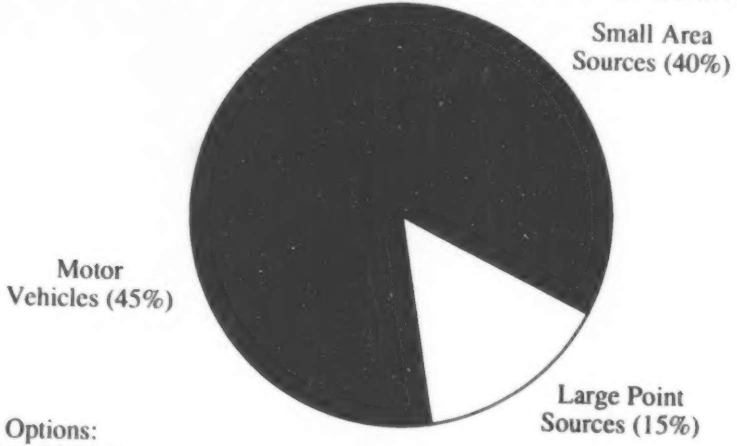


Figure 1

Motor Vehicles Contribute a Large Portion of Urban Hydrocarbon Emissions



Control Options:
- Motor Vehicles
- Small Sources such as Dry Cleaners, Bakeries, and Printers
- Driving Restrictions
- Factories and Other Large Sources

Alternative Fuels Provide Large Reductions at Low Cost

Figure 2

Motor Vehicles are Responsible for a Majority of our Air Toxics Problem

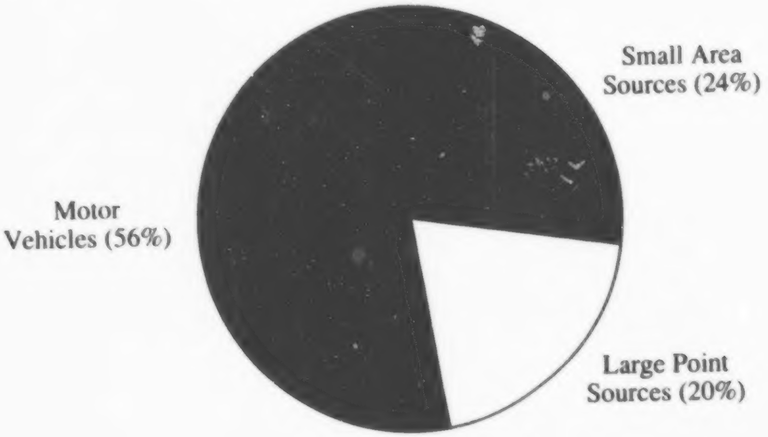


Figure 3

President's Program Will Affect Our Dirtiest Cities

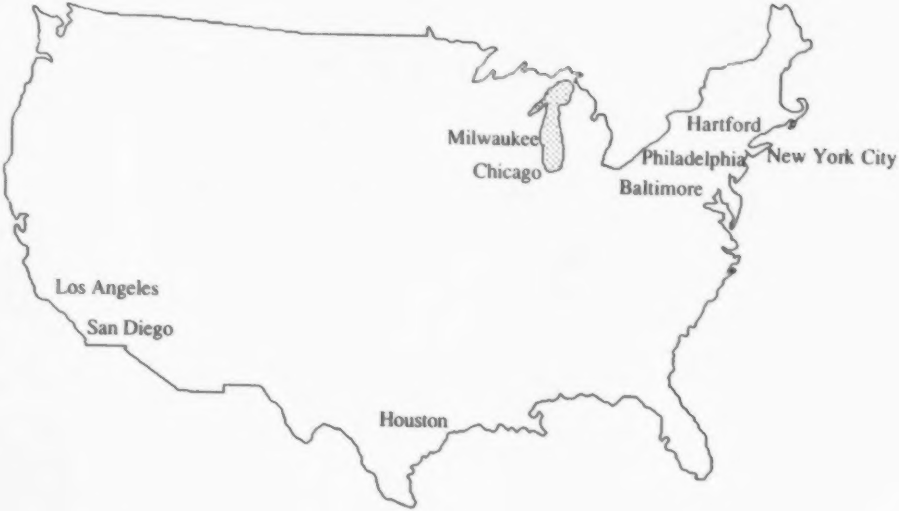


Figure 4

The President's Clean Fuels Program is Fuel and Technology Neutral

- 30 Percent of New Vehicles in Dirty Areas Must be Much Cleaner than Other New Vehicles.
- EPA will Promulgate Emissions Performance Standards:

	% Reductions	
	1995	2000
Hydrocarbons	30	80
Toxics	40	90

- Market Based: Industry is Challenged to Meet Standards in the Most Cost-Effective Manner -- Any Combination of Engine and Fuel.
- EPA will Assure that Fuels Match Cars.
- Similar to Introduction of Unleaded Gasoline in the 1970's.

Figure 5

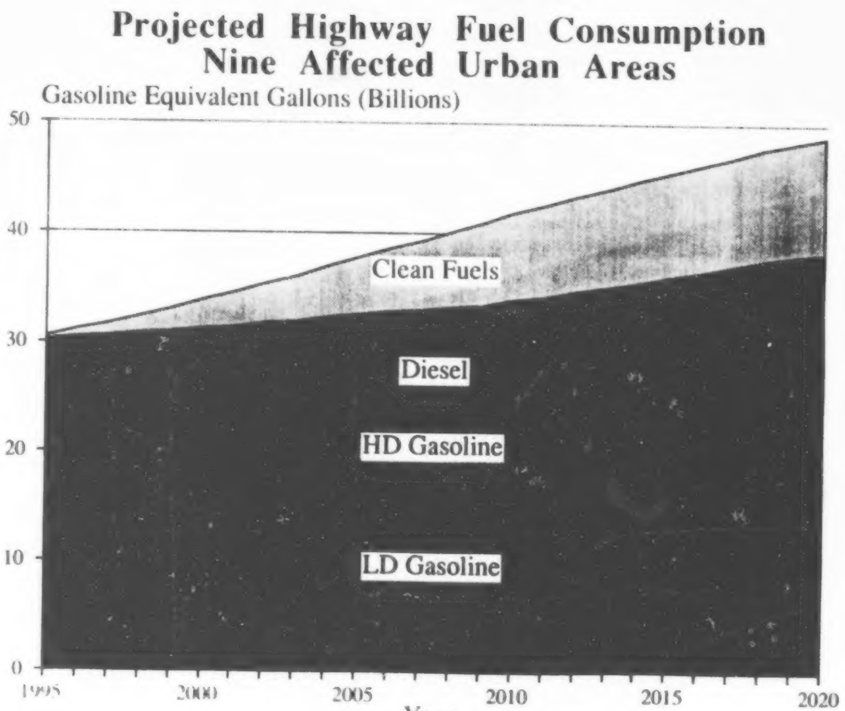

Projected Highway Fuel Consumption
Nine Affected Urban Areas
Gasoline Equivalent Gallons (Billions)
50
40
30
20
10
0
Clean Fuels
Diesel
HD Gasoline
LD Gasoline
1995
2000
2005
2010
2015
2020
Year

Figure 6

Will Consumers Buy Clean Alternative-Fueled Vehicles?

- Program is Designed to Minimize Consumer Reluctance.
- Initial Vehicles will be Flexible Fuel or Dual Fuel Vehicles.
  - Few changes from gasoline-only vehicle
  - Can operate on gasoline
  - Should perform better on clean fuels
- Fuel will be Conveniently Available.
- Automakers will Design, Promote, and Price Vehicles to Ensure that Required Number of Vehicles are Sold.

Figure 7

DISASTERS GENERATE POLICY CRISIS MANAGEMENT

David J. Zwiesler
Director
Division of Energy Policy
Indiana Department of Commerce

A decade ago this group would have been addressing the importance of energy to the economy. At that time double digit inflation and unemployment were at the top of the national agenda. It was obvious to everyone that the rapid escalation of energy prices during the 1970s had contributed significantly to the state of the economy.

Today acid rain and global warming are at the top of the national agenda and it is obvious to everyone that energy use and production contribute significantly to the state of the environment. Economists cannot fully document the long term impacts and linkages between energy use and climatic change. Even though these interrelationships are not completely understood, as energy specialists it is our job to ensure that decision makers are aware of the synergistic relationships involved with energy, environment and economics.

Here in the midwest there is substantial concern with the outcome of pending acid rain legislation. Under the President's proposal, Indiana that produces approximately 7.5% of the SO_2 emissions nationwide, would be required to achieve about 12% of the national reductions. This is because over 99% of Indiana's electricity is generated from coal. While we are very supportive of reducing emissions and cleaning up the environment, we are concerned about the price of reducing these emissions.

The President and the Congress are to be commended for their stand on clean air, but there are refinements needed to the president's acid rain proposal to ensure that it is fair and equitable as well as effective. Those

Midwestern states whose coal resources have historically met the region's energy needs, should not be forced to bear the brunt of the cost.

The Federal Power Administration projects and the relatively cheap power they produce gave a tremendous economic boost to the areas they serve. These were federally funded projects as were the S & L bail out or huge water reservoir projects in the west. These projects were in the national interest and the economic growth or solutions they engendered has benefited the whole country. I believe that acid rain abatement is analogous in that it benefits the entire country. Therefore, it is appropriate that federal dollars be used to pay a portion of the costs or other mechanisms such as cost sharing be a part of the solution.

The National Energy Strategy being developed by the United States Department of Energy should be based on energy self-sufficiency and should make use of our natural resources cleanly and efficiently. Rising U.S. dependence on imported crude oil and middle Eastern instability are potential threats to our economic and national security. At the same time we are becoming increasingly dependent on foreign oil this country is taking major environmental initiatives. The price for cleaning up the U.S. environment will be expensive and even though not all aspects can be documented scientifically, growing public concern is demanding action. Many members of the environmental movement believe that we must return to a pristine state of nature. A reconciliation between main-line environmental groups, energy interests and economic development is needed to ensure that the concerns of all groups are balanced. Sustainable Development is one approach that can be examined. That is, economic growth that's also environmentally sensitive and will benefit people indefinitely, much like sustainable agriculture.

The midwest has long been a bastion of manufacturing; however, the region is growing in non-manufacturing sectors as well. An example of this change is the growth of the financial services section, and other similar developments in cities like Columbus, Ohio, Indianapolis, Cleveland, St. Louis, and minneapolis. Many of the "new" non-manufacturing activities are highly dependent of sophisticated electronic equipment used to store, process, and transmit huge amounts of information. This equipment requires extremely reliable, high quality electric power, in surprisingly large quantities. Moreover, the office buildings that house these new forms of economic activity also require large amounts of electricity to heat, cool, and light. Far from reducing the need for electric power, economic restructuring in the midwest will continue to put more demands on generating capacity, and make supply interruptions and voltage irregularities increasingly costly and difficult to tolerate.

We have been living on the excess capacity created during the 1970s for over a decade. We cannot continue to do so. The first evidence of problems in the midwest was seen last summer. Ohio, Illinois, and Indiana were analyzed in a study that suggested, in total, these states will require 15,000 megawatts of additional base load generating capacity beyond what is now being planned by the end of the century.

Coal is still the major fuel used for electric generation in this region. Clean air legislation could cause a significant reduction in regional capacity. Clean coal technologies offer the promise of environmentally acceptable coal use for power production. Their implementation has been delayed by regulatory uncertainty. Utilities delayed taking action for fear of being penalized. A legislatively imposed standard could be based on reduction of emissions on a given date, an untried technology could be less successful then projected, or a specific emission control technology could be mandated for existing facilities.

The select use of natural gas for the generation of electricity shows great promise for improvement of air quality while still allowing extensive use of coal. Select use process technologies include: fuel oil displacement, co-firing, reburn and reburn/enhanced sorbet injection. Co-firing natural gas with coal seems to offer many benefits including SOx and NOx reduction, and boiler efficiency improvement.

Further we should look at the electric transmission system, and should consider examining that system so it meets our future needs. The ability to "wheel" power from one system to another can enable us to shift power from "capacity rich" systems to where it is urgently needed. An expanded grid system could bring a valuable economic development tool to depressed rural communities as well as other areas needing additional power to meet base load or peaking requirements.

A national energy policy should encourage research, development and implementation of alternative energy sources. We need to adequately fund alternative energy research so that this area is given the chance it deserves even with its regional disparities.

The salience of environmental issues has resulted in resurgence of recycling projects. Most citizens are willing to make some commitment to recycling. As we well know there is and energy efficiency payoff in recycling. Of course, without well developed markets for recycled products the mere act of recycling is futile. Case in point is the glut of newsprint flooding the market far overwhelming the demand. Even small steps like Indiana's recently adopted requirement that the State purchase certain items with a recyclable content help.

Support should be given such vehicular fuels as ethanol, methanol, propane and compressed natural gas. Reformulated gasoline for older vehicles as well as hold promise for environmentally acceptable fuels.

A lesson learned during the last decade is that energy efficiency is our best energy investment and it should be encouraged. One tactic being adopted in some parts of the country to delay the building of additional needed capacity is our old friend conservation. To use energy inefficiently is to waste it. The kilowatts not used because more efficient lighting is installed in a factory are kilowatts available to drive the motors used to produce finished goods. In a least cost utility planning framework, conservation may give us the time we require to adjust to new emissions standards. If we include environmental and other societal costs in our energy planning, it is the strongest weapon in our arsenal because it meets all the criteria of economics, environment and security.

The 1980s saw major changes in federal regulatory policy; more needs to be done to simplify the rules of the regulatory arena and to reduce the regulatory risks faced by utilities and other energy producers. However, just as all politics are local, ultimately all energy decisions are local or at least have major local ramifications. Many states have taken and active role participating in the federal process by testifying in regulatory hearings and working with their Congressional delegations. State and local government must take and active role in helping to devise and implement a national policy. One of the strengths of federalism is the opportunity for local government to be the proving ground for new or untried regulatory techniques. It is an opportunity to try unique approaches, thus we should not believe that there is a "single formula or manual approach." Problems, while similar, will need individual solutions tailored to specific needs.

Indiana, like many other states, is trying new regulatory approaches. Recent legislation allows the innovative disposal of fly ash, the rate basing of certain costs associated with implementing a clean coal technology in a power plant, a least cost planning approach to the construction of generating facilities, and a rolling prudence review of new construction.

The Indiana statute dealing with the regulation of solid and hazardous waste has been amended to allow, with the appropriate environmental safeguards the use of fly ash for: The extraction or recovery of materials and compounds contained within coal ash; bottom ash as and anti-skid material; raw material for manufacturing another product; mine subsidence, mine fire control, and mine sealing; structural fill, when combined with cement, sand, or water to produce a controlled strength fill material; or as a base in road construction.

Even though, we are still wrestling with the problems inherent in implementing this law, it opens up a range of alternative fly ash disposal for use.

The section of the Indiana Code dealing with utility legislation has been amended to allow a utility to recover as operating expenses those costs associated with research, design, engineering and preconstruction costs for applying a clean coal technology at a facility. Before a utility can make use of this mechanism to finance a technology, the utility must receive approval from the Indiana Utility Regulatory Commission. At a formal hearing the Commission reviews the costs for construction and implementation of the clean coal technology against the costs of installing alternative pollution controls, whether the clean coal technology extends the useful life of the existing generating facility, the potential reduction of pollutants, and the potential success of the project. The first petition for a certificate of public convenience and necessity under this statute will be heard on November 27, 1989.

Indiana law requires electric utilities obtain a "Certificate of Need" prior to constructing any new generating facility. In acting upon any petition for the construction, purchase, or lease of any facility for the generation of electricity, the commission shall take into account:

1. the applicant's current and potential arrangement with other electric utilities for:
   a. the interchange of power;
   b. the pooling of facilities:
   c. the purchase of power; and
   d. joint ownership of facilities; and
2. other methods for providing reliable, efficient, and economical electric service, including the refurbishment of existing facilities, conservation, load management, co-generation and renewable sources.

In other words before constructing a new power plant, Indiana utilities are required to investigate alternate sources of electric energy in a least cost utility planning framework. Indiana law also allows a utility that has completed the Certificate of Need process to opt for an annual review of the project. Under this option if the commission approves the construction and the cost portion of the facility under review, it can be brought into the rate base without challenge on the basis of excessive cost or inadequate quality control. If the commission disapproves of all or part of the construction or cost of the portion of the facility under review, the commission may modify or revoke the certificate. If the public utility then cancels construction of the facility, it may subject to certain conditions recover, over a reasonable period of time, through rates the amount of its investment in the facility along with a reasonable return on the unamortized balance, to the extent the construction and the cost were approved previously by the commission. We hope this provision will remove some of the uncertainty involved in the construction of new generating capacity.

In conclusion, obvious responses to the economic dislocations imposed by energy price escalation, supply disruptions, and energy security concerns in the 1970s were increased energy conservation, energy efficiency, greater attention to our indigenous energy resource, the development of alternative energy, regulatory reform and the development of a national energy policy. These same responses are obvious items in our current environmental agenda with some modifications. We can use the experience and expertise we have gained over the past 10 years to implement present day strategies.

ENERGY AND ENVIRONMENT: POLICY OPTIONS AND OPPORTUNITIES

Robert Miller
Air Quality Division
Michigan Department of Natural Resources

This presentation will encompass seven items that have to be elements of any energy-environmental policy program.

The first is acceptance. One of the earlier panelists said that the Clean Air Act will be re-authorized. Surprisingly, I find that there are still many people that do not accept that. In my judgment it is going to happen. There will be a Clean Air Act. It will address acid rain, ozone, air toxins, PM10, permitting, and it will have tough penalty requirements. My message to the industrial community is that it is time to wake up and accept the fact the Clean Air Act is going to be re-authorized.

As a result of this re-authorization, there will have to be new state laws. If any state refuses to enacted new laws and new programs then there will be clear tough federal penalties. That is, there will be provisions built into the Clean Air Act that will be much more onerous, much more difficult, and much more expensive than anything the State would enact.

That brings me to my second point. The new policy has to include cooperation between the industrial, the environmental, and the regulated community. If industry does not cooperate in the development of the program for implementing energy policy such as the Clean Air Act, then its clearly going to get "rolled over." There are some good examples of that. The electric utilities' position on Acid Rain is an example. It appears to me that this industry still has not accepted the fact that there is going to be a Clean Air Act addressing the acid rain problem. Up until very recently (and possibly even at the present time) utilities have acted as though the best policy was to try to prevent any action on the Clean Air Act. As a result where are we today? We are at the point where there will surely be a Clean

Air Act dealing with acid rain. It will be tough legislation, and probably will not involve any kind of national subsidy to assist the high sulfur coal states, the mining interests and the utility interests in the Midwest.

I honestly believe that if the utilities had cooperated earlier, they would not have gotten "rolled over" in this fashion. I think if they had worked cooperatively on the passage of Clean Air Act Amendments in the recent past, even as recently as a year ago, they might have achieved legislation that would have included a subsidy to help Midwest utilities deal with the acid rain problem. As a result of their opposition, midwest utilities and midwestern mines are facing very onerous implications.

The third element is a tough one, and that is developing an understanding of what is going on. We will have bad policy if we do not have some ability to anticipate the future and to understand where we are in the whole world picture. To emphasize this point of how important it is to comprehend what is going to happen in the next ten years, I can cite a number of things that we did not have a little more than a decade ago. We did not have Super Fund. We did not have hydrologists in our environmental programs. We had no VOC violations. We had no VOC abatement programs. We had no pretreatment standards. We had no such thing as zero discharge. We had no particular concern for air toxins – for how they affect the waters and bio-accumulation. We had no formaldehyde controls. We had no DNA engineering. We had no recombinant permits. We had no risk assessment. We had no daily reporting requirements. We had little forced public involvement. And if you think that those were big changes, wait until you see what is going to be coming in the next ten years. To be able to anticipate the future and understand what is coming I think its really important to our policy future.

I am up to number four. Obtaining the understanding that I talked about earlier will involve a big training element in our development of policy. It's going to be a big job, even for us professionals, to understand the Clean Air Act alone. We are advocating that the EPA spend at least 2% of its budget in the next year on training to get people up to speed on issues such as the new Clean Air Act. I would suggest that any company that plans on hiring five people to develop their compliance plan had probably better hire six. In this way, they will be able to devote 20% of staff time to keep up with the technology and to getting the training that is needed.

Number five: Our future policy will have a large conservation element. I am troubled by the talk of the cheap natural gas. I think that as a society we are making a mistake by wasting a natural resource such as natural gas that future generations will wish that we had not squandered. Conservation to me involves pollution prevention that includes substituting materials, substituting solvents, and getting rid of the sources of pollution. It probably means changing life style. New and different forms of transportation are needed as opposed to doing it the way we always have in the past.

Conserving electricity, as exemplified by using fluorescent bulbs that use a fraction of the electricity of the old incandescent bulb.

The sixth element I think will be a regional approach to the energy/environment future. This has been mentioned earlier with respect to ozone. We all know, of course, that acid rain is a long range transport issue, but visibility is also a long range transport issue. PM10 involves long range transport; air toxins involve long range transport. One of our big issues here in the Midwest is getting the toxins out of the air that are impacting the waters. In Michigan we have a fish advisory on every single lake in the State, advising people to limit their consumption of fish because of toxins. And a great portion of those toxins come from air deposition in the water. When the rest of the country looks at their lakes they are going to find the same thing. Other places just have not looked, but when they do they will find toxins. One of our early studies was on a lake on Isle Royale where they found toxaphene, which is a pesticide used on cotton in the South of the United States and in Mexico. We will have to think regionally about these issues.

And finally, number seven. Our policy will have to have an element of thought for the future. Our past approach that tried to address these issues on a short-term, quick fix basis is not any good anymore. We are passing on to our grandchildren a national debt that is astronomic, and AIDS. Will we pass on to them an ozone layer that does not protect us from ultra violet radiation any longer? Will we pass on to them a world where we have used up our precious natural resources? Will we pass on to them an environment where resources like the Great Lakes are contaminated? I believe that the answer is no, we will not. As a society we have decided that such a future is unacceptable. A reasonable environment for future generations will not occur automatically. We must actively take the future into account in our energy and environmental policy planning.